HOUSE OF COMMONS

Issue No. 46

Wednesday, May 25, 1988

Chairman: Barbara Sparrow

CHAMBRE DES COMMUNES

Fascicule nº 46

Le mercredi 25 mai 1988

Présidente: Barbara Sparrow

Minutes of Proceedings and Evidence of the Standing Committee on

Energy, Mines and Resources

Procès-verbaux et témoignages du Comité permanent de

L'énergie, des mines et des ressources

RESPECTING:

Main Estimates 1988-89: Votes 25, 30 and 35

INCLUDING:

Ninth Report to the House

CONCERNANT:

Budget principal des dépenses 1988-1989: Crédits 25, 30 et 35

Y COMPRIS:

Neuvième rapport à la Chambre

APPEARING:

The Honourable Gerald Merrithew,
Minister of State (Forestry and Mines)

WITNESSES:

(See back cover)

COMPARAÎT:

L'honorable Gerald Merrithew,
Ministre d'État (Forêts et Mines)

TÉMOINS:

(Voir à l'endos)

Second Session of the Thirty-third Parliament,
1986-87-88

Deuxième session de la trente-troisième législature,
1986-1987-1988

23717—1

STANDING COMMITTEE ON ENERGY, MINES AND RESOURCES

Chairman: Barbara Sparrow

Vice-Chairman: Aurèle Gervais

Members

Paul Gagnon
Len Gustafson
Russell MacLellan
Lorne Nystrom
Bob Porter—(7)

(Quorum 4)

Eugene Morawski
Clerk of the Committee

COMITÉ PERMANENT DE L'ÉNERGIE, DES MINES ET DES RESSOURCES

Présidente: Barbara Sparrow

Vice-président: Aurèle Gervais

Membres

Paul Gagnon
Len Gustafson
Russell MacLellan
Lorne Nystrom
Bob Porter—(7)

(Quorum 4)

Le greffier du Comité
Eugene Morawski

Published under authority of the Speaker of the House of Commons by the Queen's Printer for Canada

Available from the Canadian Government Publishing Center, Supply and Services Canada, Ottawa, Canada K1A 0S9

Publié en conformité de l'autorité du Président de la Chambre des communes par l'Imprimeur de la Reine pour le Canada

En vente: Centre d'édition du gouvernement du Canada, Approvisionnements et Services Canada, Ottawa, Canada K1A 0S9

REPORT TO THE HOUSE

Friday, May 27, 1988

The Standing Committee on Energy, Mines and Resources has the honour to present its

NINTH REPORT

In accordance with its Order of Reference of Tuesday, February 23, 1988, your Committee has considered Votes 1, 5, 10, L20, 25, 30, 35, 40, 50 and 55, under ENERGY, MINES AND RESOURCES in the Main Estimates for the fiscal year ending March 31, 1989, and reports the same.

A copy of the relevant Minutes of Proceedings and Evidence (*Issues Nos. 43, 44, 45 and 46, which includes this Report*) is tabled.

Respectfully submitted,

BARBARA SPARROW,
Chairman.

RAPPORT À LA CHAMBRE

Le vendredi 27 mai 1988

Le Comité permanent de l'Énergie, des mines et des ressources a l'honneur de présenter son

NEUVIÈME RAPPORT

Conformément à son ordre de renvoi du mardi 23 février, 1988, votre Comité a étudié les Crédits 1, 5, 10, L20, 25, 30, 35, 40, 50 et 55, sous la rubrique ÉNERGIE, MINES ET RESSOURCES du Budget principal des dépenses pour l'année financière le 31 mars 1989 et en fait rapport.

Un exempaire des Procès-verbaux et témoignages s'y rapportant (*fascicules n^os 43, 44, 45 et 46, qui comprend le présent rapport*) est déposé.

Respectueusement soumis,

La présidente,
BARBARA SPARROW.

MINUTES OF PROCEEDINGS

WEDNESDAY, MAY 25, 1988
(70)

[*Text*]

The Standing Committee on Energy, Mines and Resources met at 3:40 o'clock p.m., in Room 371 West Block, this day, the Chairman, Barbara Sparrow, presiding.

Members of the Committee present: Len Gustafson, Russell MacLellan and Barbara Sparrow.

Acting Members present: John Parry for Lorne Nystrom and Stan Schellenberger for Paul Gagnon.

In attendance: Dean Clay, Consultant; Lawrence Harris, Researcher.

Appearing: The Honourable G. Merrithew, Minister (Forestry and Mines).

Witnesses: *From the Ministry of Forestry and Mines*: Pierre O. Perron, Associate Deputy Minister; Stuart Mensforth, Assistant Deputy Minister, Finance and Administration; Marc Denis Everell, Assistant Deputy Minister, Mineral and Energy Technology Sector; D.C. Findlay, Director General, Continental Geoscience and Mineral Resources; Nancy Mitchell, Director, Coal Division, Mineral Policy Sector.

The Committee resumed consideration of its Order of Reference dated February 23, 1988, relating to the Main Estimates 1988-89. (*See Minutes of Proceedings and Evidence dated May 11, 1988, Issue No. 43*).

The Chairman called Votes 25, 30 and 35 under Energy, Mines and Resources.

The Minister made an opening statement and with the other witnesses, answered questions.

It was agreed,—That Votes 1 to 55 carry severally.

ORDERED,—That the Chairman report all Votes under Energy, Mines and Resources in the Main Estimates for the fiscal year ending March 31, 1989.

At 5:07 o'clock p.m., the Committee adjourned to the call of the Chair.

Eugene Morawski
Clerk of the Committee

PROCÈS-VERBAL

LE MERCREDI 25 MAI 1988
(70)

[*Traduction*]

Le Comité permanent de l'énergie, des mines et des ressources se réunit aujourd'hui à 15 h 40, dans la pièce 371 de l'édifice de l'Ouest, sous la présidence de Barbara Sparrow, (*présidente*).

Membres du Comité présents: Len Gustafson, Russell MacLellan et Barbara Sparrow.

Membres suppléants présents: John Parry remplace Lorne Nystrom; Stan Schellenberger remplace Paul Gagnon.

Aussi présents: Dean Clay, conseiller; Lawrence Harris, chargé de recherche.

Comparaît: L'honorable G. Merrithew, ministre (Forêts et Mines).

Témoins: *Du ministère des Forêts et Mines*: Pierre-O. Perron, sous-ministre associé; Stuart Mensforth, sous-ministre adjoint, Finances et administration; Marc Denis Everell, sous-ministre adjoint, Secteur de la technologie et de l'énergie; D.C. Findlay, directeur général, Direction de la géologie du continent et des ressources minérales; Nancy Mitchell, directeur, Division du charbon, Secteur de la politique minérale.

Le Comité reprend l'étude de son ordre de renvoi du 23 février 1988 relatif au budget principal des dépenses de 1988-1989. (*Voir Procès-verbaux et témoignages du 11 mai 1988, fascicule nº 43*).

La présidente met en délibération les crédits 25, 30 et 35 inscrits sous la rubrique Energie, Mines et Ressources.

Le Ministre fait une déclaration préliminaire, puis lui-même et les autres témoins répondent aux questions.

Il est convenu,—Que les crédits 1 à 55 soient respectivement adoptés.

IL EST ORDONNÉ,—Que la présidente fasse rapport de tous les crédits inscrits sous la rubrique Energie, Mines et Ressources du Budget principal des dépenses pour l'exercice financier se terminant le 31 mars 1989.

À 17 h 07, le Comité s'ajourne jusqu'à nouvelle convocation de la présidente.

Le greffier du Comité
Eugene Morawski

EVIDENCE

[*Recorded by Electronic Apparatus*]

[*Texte*]

Wednesday, May 25, 1988

• 1541

The Chairman: I call to order the Standing Committee on Energy, Mines and Resources. The notice of the meeting has been circulated. The orders of the day are Main Estimates 1988-89 on votes 25, 30 and 35 with the Mines Department.

Appearing before the committee today, we have the Hon. Gerald Merrithew, Minister of State for Forestry and Mines. We welcome you, Mr. Minister. It is always a privilege to have you appear before the committee, not only on estimates, but also on other subjects we have been discussing and doing research into. Perhaps you have some opening remarks, and then my colleagues and I will have some questions for you.

Hon. Gerald Merrithew (Minister of State (Forestry and Mines)): Thank you very much, Madam Chairman. I have a statement to make and some people to introduce. I would like to take this opportunity for the sake of the record and for the sake of your committee to outline some of the changes we have made this year, which are therefore reflected in Main Estimates 1988-89.

Maybe I could start off by introducing some of our people. With me are Dr. Pierre Perron, Associate Deputy Minister; Dr. Marc Denis Everell, Assistant Deputy Minister, Mineral and Energy Technology Sector; Stuart Mensforth, Assistant Deputy Minister, Finance and Administration, who therefore would be an expert on this book; Barry Lipsett, Director General, Mineral Strategy Branch of the Mineral Policy Sector; Chris Findlay, Director General, Continental Geoscience and Mineral Resources Branch; for questions on low-level waste, we have Dr. Jim McTaggart-Cowan, Director, Office of Environmental Affairs; and for the mapping side, we have Les O'Brien, Director General, Canada Centre for Mapping. If they are not all there, Madam Chairman, I am sure somebody else will be able to answer the questions in detail.

Maybe I could start by reviewing the principal objectives for the mineral side of the Department of Energy, Mines and Resources, and thus place into perspective the main estimates, which we are to address today.

Our mission is to gather, generate and transfer information and technology, and to contribute expertise and policy advice concerning the Canadian land mass, including our offshore areas, in minerals, metals and field resources. These activities are required for such purposes as land use management, economically and

TÉMOIGNAGES

[*Enregistrement électronique*]

[*Traduction*]

Le mercredi 25 mai 1988

La présidente: Je déclare la séance du Comité permanent de l'énergie, des mines et des ressources ouverte. Vous avez reçu l'avis de convocation pour cette réunion. À l'ordre du jour, l'étude du budget des dépenses, les crédits 25, 30 et 35 du ministère des Mines dans le Budget des dépenses de 1988-1989.

Nous accueillons aujourd'hui M. Gerald Merrithew, ministre d'État des Forêts et des Mines. Nous vous souhaitons la bienvenue, monsieur le ministre. C'est toujours un privilège de vous accueillir ici, au Comité, non seulement pour l'étude du budget des dépenses mais également pour toutes les autres questions qui font l'objet de nos débats ou de nos recherches. Vous avez peut-être une déclaration à faire qprès quoi mes collègues et moi-même, nous vous interrogerons.

L'honorable Gerald Merrithew (ministre d'État (Forêts et Mines)): Merci beaucoup madame la présidente. J'ai une déclaration mais j'aimerais d'abord présenter mes collègues. Je saisis cette occasion pour dire ici publiquement quels changements ont été apportés au cours de cette année, changements dont fait état le Budget des dépenses de 1988-1989.

Je pourrais peut-être commencer par vous présenter quelques hauts fonctionnaires. Je suis accompagné de M. Pierre Perron, sous-ministre associé; M. Marc Denis Everell, sous-ministre adjoint du Secteur de la technologie, des minéraux et de l'énergie; M. Stuart Mensforth, sous-ministre adjoint des Finances et de l'Administration, qui est donc un expert en la matière; M. Barry Lipsett, directeur général de la stratégie minérale du Secteur de la politique minérale; M. Chris Findlay, directeur général du continent et des ressources minérales; et pour la question des déchets à faible radioactivité nous avons M. Jim McTaggart-Cowan, directeur du Bureau des affaires environnementales et du Centre canadien de la cartographie; le directeur général, M. Les O'Brien. S'ils ne sont pas tous présents, madame la présidente, je suis certain que quelqu'un d'autre pourra répondre de façon détaillée.

J'aimerais tout d'abord passer en revue les principaux objectifs du secteur minéral du ministère de l'Énergie, des Mines et des Ressources pour ainsi placer en contexte le plan des dépenses sur lequel nous devons nous pencher aujourd'hui.

Nous avons pour mandat de rassembler, de produire et de transférer des renseignements et des données technologiques ainsi que d'assurer des services d'experts et de donner des avis en matière de politique concernant la masse continentale, y compris les régions extracôtières, les minéraux, les métaux et les combustibles du Canada. Ces

[*Text*]

environmentally sound resource development—for example, it is used very largely in mineral development, in forestry development, agriculture, and so on—public safety, security and sovereignty.

It is a department or part of a department that tends to touch upon the lives and activities of many, many activities in this country and even with our municipalities and our provincial governments.

As you can appreciate, Madam Chairman, this is a very broad assignment. MESP activities involve all parts of the country, east to west, from the very top of Canada to the 49th parallel. Obviously I cannot review today everything MESP involves. However, we will give the committee the highlights of our activities.

There are some new structural changes this year I would like to let the committee know about. Our program has undergone significant changes in the past two years, resulting in a thorough restructuring of all the sectors. Furthermore, the program, which was delivered through three sectors in 1985, is now delivered through four sectors to respond better to the mandate requirements and to technically inclined group constraints.

I would note particularly the elevation of the geological survey to full sector status. This of course means it has the direction of an assistant deputy minister. This change reflects the survey's position as a major organizational unit within the department, as the senior geoscientific organization in Canada, and as one of the foremost geoscience institutes in the world. Coincident with this elevation has been a regrouping of the units in Ottawa and the GSC's regional institutes.

• 1545

I mentioned a while ago that our activities take us clear to the north and there has been a significant revision of the mandate of our Polar Continental Shelf Project which provides logistics and organizational support for northern scientific investigations of university researchers, other government departments and the sector.

Another major aspect of the the Earth Sciences Program within the department is the creation of the Surveys, Mapping and Remote Sensing Sector, which brought together the remote sensing and mapping technologies of the department. This change marks a major turning point for the surveys and mapping operation after decades of intensive data-gathering operations and completion of a primary map coverage of Canada. The organization will henceforth focus increasingly on data management in a new partnership now being put together with provincial authorities, utilities and the private sector.

[*Translation*]

activités sont nécessaires à la gestion de l'aménagement du territoire, à la mise en valeur des ressources d'une façon rentable et dans le respect de l'environnement—par exemple, pour l'expansion dans le secteur des minéraux, des forêts, de l'agriculture et ailleurs—à la sécurité publique et à la souveraineté.

Il s'agit d'un ministère ou d'une partie du ministère qui touche aux vies et aux activités de nombreux travaux au pays et même à nos municipalités et à nos gouvernements provinciaux.

Comme vous pouvez le constater, madame la présidente, il s'agit d'une tâche très vaste. le Programme des minéraux et des sciences de la terre, PMST, travaille dans tous les coins du pays, de l'Est à l'Ouest, depuis l'extrémité Nord du pays jusqu'au 49e parallèle. Il est évident que je ne peux traiter de toutes les activités du PMST, mais je vous en exposerai les points principaux.

J'aimerais vous mettre au courant de certains changements structurels apportés cette année. Le programme a subi des changements considérables au cours des deux dernières années, provoquant une réorganisation en profondeur de tous les secteurs. En effet, le programme, qui comportait trois secteurs en 1985, en compte maintenant quatre, afin de mieux répondre aux exigences de son mandat, aux besoins de ses clients et aux restrictions de nature techniques.

Parmi les faits marquants de cette réorganisation, notons que la Commission géologique est devenue un secteur à part entière, sous la direction d'un sous-ministre adjoint. Cette modification tient compte du fait que la Commission est devenue un service de premier plan au ministère, le principal organisme géoscientifique au Canada et l'un des instituts des sciences de la terre les plus avancés au monde. Parallèlement, les services de la CJC à Ottawa et les instituts régionaux ont été regroupés.

J'ai dit un peu plus tôt que nos activités nous amènent à travailler dans le Nord et il y a eu une révision importante à apporter au mandat du projet d'étude du Plateau continental polaire qui assure des services de soutien et de logistique aux équipes de recherches scientifiques travaillant dans le Nord. Ces recherches sont effectuées par des universitaires, d'autres ministères fédéraux et des membres du secteur.

Un autre élément majeur de la réorganisation du Programme des minéraux et des sciences de la terre au sein du ministère a été la création du secteur des levés, de la cartographie et de la télédétection, qui a permis de réunir les compétences du ministère en matière de télédétection et de cartographie. Ce changement constitue un point tournant pour les activités de levés et de cartographie, après des décennies de rasemblement intensif des données d'achèvement de cartes préliminaires de l'ensemble du Canada. Désormais, ce secteur concentrera davantage ses efforts à la gestion des données, dans le cas d'une nouvelle association qui sera bientôt

[*Texte*]

A concomitant and particularly significant development in the summer of 1987 was the resolution on terms apparently satisfactory to all concerned of the proposed transfer of part of the Surveys and Mapping Branch to Sherbrooke. As you may know, this was an irritant in the system for well over 10 years and we were pleased to have it resolved. Cabinet decided to establish the Sherbrooke Institute of Cartography, a permanent division of 100 PYs.

This division will be responsible for topographical mapping of eastern Canada and associated research and development focusing on the applications of remote sensing for mapping. As I mentioned, this decision ends 10 years of uncertainty for the employees of the Surveys and Mapping Branch. I might add that the unions and others were very pleased that we at last resolved this outstanding irritant to the department.

My final comment on the Earth Sciences Programs organizational changes would be to note the restructuring of CANMET into two clearly defined and strong focal points, one branch for mineral technology and one branch for energy technology. CANMET is part of a redefined Mineral and Energy Technology Sector and will henceforth operate as a technology centre under the terms and conditions of a recently approved policy of government. This move aims at involving CANMET's clients more fully in the planning, funding and execution of technology developments carried out in-house and externally.

CANMET's first business plan was recently released and sets out the organization's intentions. The organization I have described was undertaken in recognition of the importance of research and development and the necessity to optimize the use of science and technology to enhance our industrial productivity.

We want to use the Earth Sciences Program resources to obtain the greatest possible impact on industrial innovation and efficiency and to foster more joint research and development activities with the private sector.

Madam Chairman, I would like to touch very briefly on the situation of the minerals and metals industry. At this very moment we have a very major conference going on at the Conference Centre at the Westin. It is our Mineral Outlook Conference. I think it is the largest attendance in history and there are a lot of very interested people there, perhaps well over 500. I am sure they would look forward to members of your committee meeting with them and to talking to members of the government and Members of the Parliament this afternoon.

[*Traduction*]

réalisée avec les autorités provinciales, les services publics et le secteur privé.

Un événement concomitant et particulièrement important s'est produit au cours de l'été 1987, soit le transfert, selon des modalités que tous les intéressés ont, semble-t-il, jugé acceptables, d'une partie de la Direction des levés et de la cartographie à Sherbrooke, division permanente de la Commission dotée de 100 années-personnes.

Cette division sera chargée d'établir des cartes topographiques de l'Est du Canada et d'effectuer la recherche et le développement connexes, en se concentrant sur les applications de la télédétection à la cartographie. Je le répète, cette décision met un terme à 10 années d'incertitude pour les employés de la Direction déléguée à la cartographie. J'ajouterais que le syndicat et d'autres groupes ont été très heureux que nous puissions éliminer cet important point de friction pour le ministère.

Pour terminer ma revue des changements organisationnels qu'a subi le Programme des sciences de la terre, j'aimerais souligner la restructuration du CANMET en deux services distincts et solides: une direction s'occupant de la technologie des minéraux et une direction chargée de la technologie de l'énergie. CANMET fait partie du nouveau secteur de la technologie des minéraux et de l'énergie. Il sera à l'avenir exploité comme «centre de technologie», selon les modalités fixées par une politique qui a été approuvée récemment par le gouvernement. Cette décision vise à faire participer davantage les clients de CANMET à la planification, au financement et à la mise en oeuvre des progrès technologiques réalisés au ministère lui-même et à l'extérieur.

Le premier plan d'action de CANMET, rendu public dernièrement, décrit les éléments de sa nouvelle vocation. La réorganisation dont je viens de faire état a été entreprise pour tenir compte de l'importance de la recherche et du développement ainsi que de la nécessité de recourir au maximum à la science et à la technologie pour accroître la productivité de l'industrie.

Nous voulons utiliser les ressources du Programme des sciences de la terre pour générer le plus de retombées possibles au plan de l'innovation et de l'efficacité de l'industrie et pour favoriser l'intensification des travaux de recherche et de développement conjointement avec le secteur privé.

Madame la présidente, permettez-moi maintenant d'aborder très brièvement la situation du secteur des minéraux et des métaux. À ce moment-ci, une conférence très importante a lieu au Centre des conférences de l'Hôtel Westin. Il s'agit d'une conférence sur les perspectives minérales. C'est peut-être la conférence la plus courue de l'histoire, beaucoup de gens s'y intéressent, plus de 500 personnes. Je suis certain qu'ils sont impatients de rencontrer les membres de ce Comité, du gouvernement et du Parlement cet après-midi.

[Text]

The industry went through a difficult period from 1982 to 1985, basically caused by three or four different aspects: worldwide recession, excess capacity for many commodities, new sources of international competition and of course the ongoing one, product substitution. They all contributed to a sharp fall in real prices of many mineral commodities and resultant low profitability for mining firms.

Canada's mining companies responded with significant productivity improvements, cost-cutting measures and corporate restructuring. The result is a much healthier and more competitive minerals and metals industry. In the past year an especially positive aspect has been the significant increase in metal prices. Many in the industry are now showing a well-deserved profit.

• 1550

They have gone through a very difficult time, Madam Chairman, as you and your committee know, and I think they have managed through that very difficult period and made significant productivity gains and cost-cutting measures which were difficult but necessary. As a result, I do not think you remember in Canada any large number of our mines or any of our operations closing down.

I think for that reason sometimes our managers and our senior management do not get the kind of management credit they deserve. At this time, I would like to pay tribute to them in the way they managed.

Dans l'ensemble, l'industrie a fait preuve d'une vigueur remarquable en 1987. La production minérale canadienne s'est accrue de 17.5 p. 100 pour se chiffrer à 16 milliards de dollars, la production d'or représentant à elle seule plus de 32 p. 100 de ce chiffre. En 1987 également, les travaux d'exploration ont atteint des niveaux record; de plus, 34 nouvelles mines ont été mises en exploitation au pays. Madame la présidente, nous prévoyons que 1988 sera une année tout aussi prospère.

Madam Chairman, let me now turn to the future. As I noted at the outset, the breadth of the Minerals and Earth Sciences Program activities allows me to pick up only a few highlights of the department's past and future work.

The main estimates for 1988-89 are a statement of our continued commitment to several goals and themes. They even include regional development, science and technology, environmental issues, health and safety, increased co-operation—both provincial governments and industry, improving Canada's competitive position internationally and better departmental efficiency.

You will recall that when I appeared before this committee in May 1987 I had released at that time, in fact

[Translation]

L'industrie a traversé une période difficile en 1982 et 1985. La récession mondiale, la surcapacité de production dans le cas de nombreux minéraux, l'entrée sur la scène internationale de nouveaux concurrents et la mise au point de produits de remplacement se sont conjugués pour provoquer une chute prononcée du prix réel de nombreux minéraux et, du même coup, une baisse de la rentabilité des sociétés minières.

Les sociétés minières canadiennes ont relevé le défi en prenant des mesures importantes visant à accroître leur productivité, réduire leurs coûts et à restructurer leurs activités. Grâce à ces mesures, l'industrie minière a grandement amélioré sa situation financière et sa compétitivité. La hausse considérable du prix des métaux a représenté un fait marquant au cours de la dernière année. Bon nombre de sociétés peuvent maintenant afficher des bénéfices bien mérités.

Ils ont connu des temps très difficiles, madame la présidente, vous-même et les membres du Comité le savez, et j'estime qu'ils s'en sont très bien tirés, qu'ils ont fait des gains importants sur le plan de la productivité et adopté des mesures de compression difficiles, mais nécessaires. Par conséquent, je ne me souviens pas qu'au Canada, un grand nombre de nos mines ou de nos exploitations aient dû fermer leurs portes.

J'estime donc que parfois, nos gestionnaires et nos cadres supérieurs ne se voient pas accorder le mérite qui leur est dû. Je voudrais à ce moment-ci leur rendre hommage pour leur bonne gestion.

Overall, the industry in 1987 was remarkably vigorous. Canadian mineral production jumped by 17.5% to $16 billion with gold production alone up more than 32%. Exploration activity in 1987 reached record levels and 34 new mines opened across the country. We expect, Madam Chairman, that 1988 will be an equally good year.

Madame la présidente, je voudrais maintenant me tourner vers l'avenir. Comme je l'ai souligné au début, l'éventail des activités du Programmes des minéraux et des sciences de la terre ne me permet que de noter quelques-uns des faits saillants des travaux passés et futurs du ministère.

Le Budget des dépenses principal de 1988-1989 témoigne de notre engagement à l'égard de plusieurs thèmes et objectifs. Notons le développement régional, les sciences et la technologie, les questions relatives à l'environnement, la santé et la sécurité, l'accroissement de la collaboration avec les gouvernements provinciaux et l'industrie, l'intensification de la compétitivité du Canada sur la scène internationale, ainsi que l'amélioration de l'efficacité du ministère.

Vous vous souviendrez que lors de ma comparution devant ce Comité en mai 1987, j'ai rendu publique—de

[*Texte*]

during the Mineral Outlook Conference, "The Mineral and Metal Policy of the Government of Canada". It sets out for our industry and for the mining sector a flexible, supportive and responsive role for the Government of Canada. This policy statement remains appropriate and sensitive to the needs of the mining industry and it will continue to provide the policy framework for our activities.

The free trade initiative will have significant direct benefits for the mineral industry. In early February 1988 I released a trade impact assessment for the minerals and metal sector. Canada's mineral industry depends heavily on trade and the U.S.A. is of course the most important market, taking about 71% of everything we export. The industry has been strongly supportive of this initiative; recognizing it assures long-term access to its major customer.

Very tangible examples of the government's commitment to regional development are the MDAs, or Mineral Development Agreements. My department administers these MDAs which have a total commitment of $143 million, money that is being spent in providing geological information to stimulate exploration, joint research efforts to reduce mining costs, as well as market studies to identify new opportunities. I can tell you, Madam Chairman, the MDAs are working well and the provinces are happy with them.

On exploration, we know that exploration is absolutely fundamental to a competitive and a prosperous mineral sector, and I think our new program which we announced a week or two ago, the Canadian Exploration Incentive Program—CEIP—will provide the momentum and financing necessary to maintain primary exploration. CEIP will also ensure that communities in the northern and remote areas continue to enjoy the benefits they have received as a result of recent exploration activity.

I would note, Madam Chairman, that the announcement of CEIP has been very positively received. In fact, even today at our Mineral Outlook Conference I talked to John Larch, who is the Chairman of the Prospectors and Developers Association, and he was again glowing in his comments about the program. He felt it would do the job in terms of keeping up a reasonable level of exploration activity for our mining sector.

Also, I would point out that this program is of course not reflected in the estimates before us toda. They will obviously have to be addressed in the 1988-89 supplementary estimates.

• 1555

On enviromental issues, public concern for environmental quality is increasing and both industry and government are well aware of their responsibility to

[*Traduction*]

fait, c'était au cours de la Conférence sur les perspectives minérales—«La politique du gouvernement du Canada sur les minéraux et les métaux», qui décrit le rôle souple de soutien et d'aide que peut jouer le gouvernement canadien. Cet énoncé de politique demeure approprié et adapté aux besoins de l'industrie minière, et il continuera de former le cadre de nos activités.

L'accord de libre-échange procurera d'importants avantages directs à l'industrie minière. Au début de février de cette année, j'ai rendu publique une évaluation de ses effets sur le secteur des minéraux et des métaux. Comme vous le savez, l'industrie minière canadienne est fortement tributaire du commerce extérieur, et les États-Unis représentent notre débouché le plus important; ils reçoivent près de 71 p. 100 de toutes nos exportations. L'industrie a donc fermement appuyé cette initiative, reconnaissant qu'elle assure un accès à long terme à son principal client.

Les ententes sur l'exploitation minérale constituent sans contredit un exemple très concret de l'engagement de notre gouvernement envers le développement régional. Ces ententes prévoient l'affectation de 143 millions de dollars, qui sont consacrés à la prestation de renseignements géologiques pour stimuler l'exploration, à des travaux conjoints de recherche visant à réduire les coûts, ainsi qu'à des études de marché dans le but de découvrir de nouveaux débouchés. Je puis vous assurer, madame la présidente, que ces ententes fonctionnent bien et que les provinces sont satisfaites de la situation.

Nous savons tous que l'exploration est essentielle pour assurer la compétitivité et la prospérité du secteur minier. C'est la raison pour laquelle, à mon avis, le programme que nous avons annoncé il y a une semaine ou deux, le nouveau Programme de stimulation de l'exploration au Canada (PSEC), permettra de maintenir le rythme et le financement nécessaires à l'exploration préliminaire. Dans le cadre du PSEC, les collectivités du Nord et des régions éloignées continueront de bénéficier des retombées qu'elles connaissent depuis quelques années.

J'aimerais souligner, madame la présidente, que le PSEC a été très bien accueilli. En réalité, aujourd'hui même, à notre Conférence sur les perspectives minérales, j'ai discuté avec John Larch, président de l'Association canadienne des prospecteurs et entrepreneurs, qui n'avait que des paroles élogieuses concernant le programme. À son avis, ce programme permet de maintenir un niveau raisonnable d'exploration dans le secteur minier.

Je voudrais également souligner que ce programme ne figure pas bien entendu dans le plan de dépenses qui vous est présenté aujourd'hui. Il en sera question lors du dépôt du budget des dépenses supplémentaire de 1988-1989.

Au sujet des questions environnementales, le public s'intéresse de plus en plus à la qualité de l'environnement, et l'industrie aussi bien que le gouvernement sont très

[*Text*]

maintain the quality of our natural environment. Joint research efforts with industry, such as the treatment of reactive acid mine tailings and the Acid Rain Abatement Program, will continue. On a more general level, EMR will be increasingly involved in global efforts to understand the macro-environmental changes being faced by our world.

One of our inherited problems is low-level radioactive waste. The final report of the Siting Process Task Force for a low-level radioactive waste disposal facility was released in December 1987. This report recommends a co-operative process for the siting of controversial facilities. Public response to the task force has been very positive. Two communities, Deep River and Elliot Lake, have come forward as volunteers to go through the siting process.

Recent examples of increased federal-provincial co-operation in surveying and mapping in Canada are the memoranda of understanding which I have signed with several provinces. Under these, Canada will develop national standards across the country for transmittal and exchange of geographic information in computer-processable form. All levels of government will be able to use the same map-making techniques and information. This will lead to an ever increasing saving in map production and revision costs, more informative and timely map production, and meet the increasing demands of industry for geographic information in computer-processable form.

Also, in November I signed a memorandum of understanding with a major industry association, representing a large part of the Canadian surveying and mapping community. The industry is wholeheartedly committed to this new technology, its applications, and particularly its actual and potential sales within Canada and international markets. Evidence of this confidence is shown by the fact that the industry has invested some $50 million in computer hardware and software over the past few years, and is firmly prepared to expand this investment in the future. Also, tomorrow EMR will be signing yet another memorandum of understanding, this time with the largest professional survey and mapping association in Canada, the Canadian Institute of Surveying and Mapping.

Finally, within the context of our government's science and technology policy, the scientific parts of the Mineral and Earth Sciences Program will be making an important contribution. As I have indicated, we will be working closely with the private sector and provices to ensure their priorities are reflected in our work, and that EMR's resources are combined with theirs in an efficient and timely manner so as to contribute to a larger joint

[*Translation*]

conscients de leurs responsabilités dans ce domaine. Les travaux de recherche exécutés conjointement avec l'industrie, tels que le traitement des résidus miniers acides réactifs et le programme de réduction des pluies acides, se poursuivront. Sur la scène internationale, le personnel d'EMR participera de plus en plus aux recherches sur les changements macro-environnementaux auxquels le monde doit faire face.

Un des problèmes dont nous avons hérité, c'est celui des déchets à faible radioactivité. Le rapport final du groupe de travail chargé d'établir un processus de détermination d'un site d'enfouissement des déchets à faible radioactivité a été rendu public en décembre 1987. Les auteurs de ce rapport recommandent de faire appel aux parties concernées pour déterminer l'emplacement des installations controversées. La réaction du public au rapport a été très positive. Deux collectivités, soit Deep River et Elliot Lake, ont accepté de se soumettre à ce processus.

Parmi les exemples récents de l'accroissement de la collaboration fédérale-provinciale en matière de levés et de cartographie, notons les protocoles d'entente que j'ai conclus avec plusieurs provinces. Dans le cadre de ces protocoles, le Canada établira des normes nationales concernant la transmission et l'échange de renseignements géographiques sous une forme pouvant être traitée par ordinateur. Tous les paliers de gouvernement pourront avoir accès aux mêmes données et techniques cartographiques. Cette mesure permettra d'économiser des sommes de plus en plus grandes au chapitre de la production et de la révision de cartes, d'établir des cartes plus riches et plus rapidement et de répondre aux besoins croissants de l'industrie en matière de renseignements géographiques pouvant être traités par ordinateur.

En outre, j'ai signé en novembre un protocole d'entente avec une importante association d'industries, qui représente une large partie du milieu des levés et de la cartographie au Canada. L'industrie est engagée à fond dans la mise au point de cette nouvelle technique, de ses applications et, en particulier, de ses perspectives de ventes au pays et à l'étranger. Les quelque 50 millions de dollars qu'elle a investis au cours des dernières années dans l'achat de matériel et de logiciels, ainsi que les sommes qu'elle est fermement disposée à affecter à l'avenir témoignent de la confiance de l'industrie envers cette technique. Autre exemple, demain, EMR conclura un autre protocole d'entente avec la plus importante association professionnelle de levés et de cartographie au Canada, soit l'Institut canadien de levés et de cartographie.

En dernier lieu, les services à vocation scientifique du Programme des minéraux et des sciences de la terre joueront un rôle de premier plan dans la politique gouvernementale relative à la science et à la technologie. Comme je l'ai dit, nous collaborerons étroitement avec le secteur privé et les provinces pour veiller à ce que nos travaux tiennent compte de leurs priorités et à ce que les ressources d'EMR soient combinées d'une manière

[*Texte*]

research effort. In the past year I have restructured the system of advisory committees on CANMET so I can be sure of receiving timely and essential industry input. The advisory committee for the Geological Survey Sector is also being strengthened.

Madam Chairman, my comments highlight the philosophy and directions we are heading in within the Minerals and Earth Sciences Program.

Our role is to be supportive of industry, not to intervene. We look to the private sector to assess the risks, marshall the resources and make the investment decisions. At the same time, we will be as responsive as possible to the private sector's research priorities and information requirements.

I might add, and we dealt with this issue yesterday, there is a very interesting initiative, called Tech Trends, jointly sponsored by my department and the Ministry Industry Technology Committee from the private sector, bringing in a group of people from around the world to advise our sector on what is happening in Norway, Great Britain, the United States and Australia. The numbers who attended indicated a great deal of interest.

All of the above will be done in the context of overall government priorities, including the all-important concern of budgetary restraint.

Madam Chairman, members of the committee, thank you for your time and attention. I ask for this committee's support to implement the initiatives outlined in the main estimates. I am here with my officials to answer any questions you may have and I look forward to continuing to work with all of you.

• 1600

I want at this time to express my thanks for the support of the committee. It is a department that has gone along its way essentially unnoticed but doing reasonably good work with the sector. I guess you would have to ask the people who are out there at the sharp point doing the exploration and the mining whether they appreciate the efforts of the agencies and the department that are working on their behalf. I am sure once again they will be most pleased to see members of this committee and other Members of Parliament this afternoon as they finish up another mining outlook conference.

Should I not be able to answer the technical questions, I promise you you will get answers, even if they have to follow in writing.

The Chairman: Thank you very much, Mr. Minister. Your opening remarks were extremely informative, and we certainly appreciate them.

I also want to say to you and your department a word of thanks on the new CEIP. It certainly will assist not

[*Traduction*]

efficace et opportune aux leurs pour intensifier les efforts déployés. Au cours de l'année qui s'est écoulée, j'ai restructuré le réseau des comités consultatifs sur CANMET afin de recevoir dans les plus brefs délais les réactions et opinions de l'industrie. Le comité consultatif du Secteur de la Commission géologique du Canada fait également l'objet de modifications.

Madame la présidente, mes observations illustrent la philosophie et les orientations qui sous-tendent les programmes des minéraux et des sciences de la terre.

Notre rôle consiste à aider l'industrie, non à intervenir dans ses affaires. C'est au secteur privé qu'il revient d'évaluer les risques, de réunir les ressources et de prendre les décisions en matière d'investissement. En même temps, nous satisferons dans la plus grande mesure possible aux priorités de recherche et aux besoins de renseignements du secteur privé.

J'ajouterais, et nous avons discuté de la question hier, qu'une initiative très importante, appelée *Tendances techniques*, parrainée conjointement par mon ministère et un comité de technologie industrielle du secteur privé, regroupe des personnes de différents pays qui conseillent notre secteur sur ce qui se fait en Norvège, en Grande-Bretagne, aux États-Unis et en Australie. Les personnes qui y ont participé se sont montrées très intéressées.

Tout ce qui précède sera fait selon les priorités globales du gouvernement, notamment les indispensables compressions budgétaires.

Madame la présidente, membres du Comité, je vous suis reconnaissant de m'avoir accordé votre temps et votre attention. Je vous demande d'appuyer les initiatives décrites dans le plan de dépenses. Mes fonctionnaires et moi-même nous ferons un plaisir de répondre à vos questions, et j'espère pouvoir continuer à travailler avec vous tous.

Je tiens maintenant à remercier le Comité de son appui. Les activités du ministère passent peut-être inaperçues, mais il fait du bon travail dans ce secteur. J'imagine que c'est à ceux qui sont à la fine pointe de l'exploration et de l'exploitation minières qu'il faut demander s'ils apprécient, à leur juste valeur, les efforts que déploient les organismes et les ministères dans leur intérêt. Je le répète, ils auront grand plaisir à revoir les membres du Comité et d'autres députés cet après-midi, aux termes de la Conférence sur les perspectives minières.

Si je ne puis répondre à des questions d'ordre technique, je vous promets que vous obtiendrez des réponses, même si elles doivent suivre par écrit.

La présidente: Merci bien, monsieur le ministre. Votre introduction était des plus instructives, et nous vous en savons gré.

Je tiens également à vous remercier, vous et votre ministère, pour le nouveau PSEC. Nul doute que non

[*Text*]

only in mining but in the petroleum business. They are both high-risk businesses and they do need some sort of incentive to keep them going.

Mr. MacLellan: On the CEIP, Mr. Minister, I was wondering where private partnerships stand in mining. Are they included in the CEIP?

The Chairman: As I understand it—and of course the minister is perfectly free to answer—as far as the junior mining companies are concerned, most of them are public, Mr. MacLellan. So the problem appears to be in the oil and gas business.

Mr. MacLellan: It is not a problem in the mining sector.

Mr. Merrithew: Madam Chairman, you are exactly right. In the mining sector they tend to operate in a different way. They tend to be public, and they are willing and able to flow the benefits through to those who have picked up shares through the flow-through share process.

Incidentally, I can announce here, because it was announced this morning, that we will have a paper available for the industry. We have seven months to put the program into effect, because we are going to continue their earned depletion of 33 1/3% to the end of this year. That paper will be ready at the end of the month. It will go out to the industry. We want their advice. We want to consult with them. We want to make sure the program we set up works for them, yet at the same time protects the interest of the Canadian taxpayer, who will be footing a good deal of the bill for this.

But on your question, it is essentially no problem for the mining side at all.

Mr. MacLellan: On the mineral and metal commodities activity, the amount of expenditures is going to be reduced considerably. Is that because of the completion of the Chatham fluidized bed combustion project and the Charlottetown Cold Water Project?

Mr. Merrithew: I will ask somebody to respond in detail, but yes, those two programs are essentially completed. I attended the official opening of the circulating fluidized bed project in Miramichi. We have made a contribution of $37 million, I believe, to the new coal technologies. The cold water demonstration unit is essentially completed as well.

Dr. Pierre O. Perron (Associate Deputy Minister, Department of Energy, Mines and Resources): You are talking specifically about the phase-out of the Coal Demonstration Program.

Mr. MacLellan: The reduced budget for the mineral—

Dr. Perron: This program was initiated in 1982, if I remember correctly, and was extended for a couple more

[*Translation*]

seulement le secteur minier, mais aussi le secteur pétrolier, pourront en profiter. Ce sont deux secteurs comportant des risques élevés, aussi leur faut-il quelque encouragement pour qu'ils persévèrent.

M. MacLellan: Au sujet du PSEC, monsieur le ministre, je me demande quel est le rôle attribué aux associations privées en matière d'exploitation minière. Figurent-elles dans le PSEC?

La présidente: Si je comprends bien—et certes le ministre est tout à fait libre de vous répondre—pour ce qui est des sociétés minières moins importantes, la plupart sont du secteur public, monsieur MacLellan, le problème semble donc se poser dans le secteur du pétrole et du gaz.

M. MacLellan: Il n'y a pas de problème dans le secteur minier.

M. Merrithew: Madame la présidente, vous avez parfaitement raison. Le secteur minier a tendance à agir de façon différente. Il favorise la participation du secteur public, il est disposé à faire profiter ceux qui se sont procuré des actions accréditives.

Soit dit en passant, je peux bien en parler ici, car on l'a annoncé ce matin, nous avons rédigé une brochure pour la gouverne de l'industrie. Nous disposons de sept mois pour mettre le programme en oeuvre, car la déduction gagnée de 33 1/3 p. 100 s'appliquera jusqu'à la fin de l'année. Ce document sera prêt à la fin du mois. Il sera diffusé à l'industrie. Nous tenons à recueillir son avis. Nous tenons à la consulter. Nous voulons nous assurer que ce programme lui est profitable, en même temps qu'il protège les intérêts des contribuables canadiens, qui vont en assumer une bonne partie des frais.

J'en reviens à votre question, en fait, cela ne pose aucun problème pour le secteur minier.

M. MacLellan: Pour ce qui est du secteur des minéraux et des métaux, on va diminuer sensiblement le montant des dépenses. Pourquoi? Est-ce parce que le projet de combustion en lit fluidisé à Chatham et celui d'alimentation en combustible charbon-eau, à Charlottetown sont terminés?

M. Merrithew: Je demanderais à quelqu'un de vous fournir les détails, mais il est vrai que ces deux programmes sont plus ou moins terminés. En fait, j'ai assisté à l'inauguration officielle de l'installation de combustion en lit fluidisé à Miramichi. Sauf erreur, nous avons alloué 37 millions de dollars à cette nouvelle technologie du charbon. Quant à l'unité de démonstration à combustible charbon-eau, je crois que les travaux sont aussi terminés.

M. Pierre O. Perron (sous-ministre associé, ministère de l'Energie, des Mines et des Ressources): Vous faites allusion, n'est-ce-pas, à la cessation progressive du programme de démonstration du charbon.

M. MacLellan: La baisse des budgets dans la catégorie des minéraux. . .

M. Perron: Ce programme a débuté en 1982, sauf erreur, et s'est prolongé durant quelques années, avec

[*Texte*]

years, with Treasury Board's authorization, to complete a couple of projects. These have now come to an end, as of April 1 of this year. Therefore no funds are provided for the Coal Demonstration Project beyond that date.

Mr. MacLellan: The whole mineral and metal commodities activy is reduced. Is that because these programs are finished and no other programs are being started. Is that it?

Dr. Perron: Yes.

Mr. MacLellan: What is the plan? Are other projects going to be initiated? What I am concerned about, largely, is where we go from here. These are good programs. Can we honestly say the work in these fields has been completed? If so, what have we learned and where do we stand with the Cold Water Project and fluidized bed project?

• 1605

Dr. Perron: I guess. Mr. MacLellan, one should say that the work is never completed in the research and development and there is so much one can do. There always comes a point where the private sector initiative has to take the relay. In the case of the Coal Demonstration Program, major investment has been done in the framework of the program, to a point where we have learned a great deal about fluidized bed combustion through the Chatham demonstration project, and as well on the Carbogel type of fuels.

These projects will mature and we will see whether our private sector picks up the relay and whether they go a little further. We are quite confident that they will in due time.

As to whether there will be a need for more programs or more activities of that nature, you will be aware, undoubtedly, that the deputy prime minister has convened a special task force with the premiers to discuss the possibilities of increasing the amount of western coal going into the Ontario market. This has led to the formulation of a certain number of initiatives that are now being actively considered by the deputy prime minister and the premiers. They were planning to meet some weeks ago. Unfortunately, the meeting was cancelled because of some unforeseen circumstances. We expect to have a decision on that front in the very near future.

Mr. MacLellan: The deputy prime minister's group is for the long range, but I am concerned now that this money has been spent on the fluidized bed project and the coal and water project. You say that it is now up to the private sector to pick it up. What has been developed to be picked up? What exactly has the government brought these two projects to that would be something the private sector would be interested in developing further?

Mr. Merrithew: The total cost of the coal utilization program was $78 million, of which $37.8 went to the one

[*Traduction*]

l'assentiment du Conseil du Trésor, afin de terminer certains travaux. Le programme a donc pris fin le 1[er] avril dernier. À partir de cette date, aucun montant n'est prévu pour le programme de démonstration de la houille.

M. MacLellan: Il y a des baisses dans tous les secteurs des activités relatifs aux minéraux et aux métaux. Est-ce que c'est parce que ces programmes sont terminés et qu'aucun autre programme n'a été mis en route?

M. Perron: C'est exact.

M. MacLellan: Quels sont vos plans? D'autres projets sont-ils envisagés? Ce qui m'intéresse, surtout, c'est la suite qui est prévue. Il s'agissait de bons programmes. Est-il exact que dans ce domaine, les travaux sont terminés? Alors, qu'avons-nous appris et où en sommes-nous à l'égard du lit fluidisé et du combustible charbon-eau?

M. Perron: J'imagine, monsieur MacLellan, que l'on peut dire qu'il y a toujours à faire en matière de recherche et de développement, mais qu'on ne peut faire que certaines choses. Il arrive toujours, à un moment donné, que le secteur privé doit prendre la relève. Dans le cas du programme de démonstration du charbon, des investissements importants ont été effectués, à telle enseigne, que nous en avons appris beaucoup au sujet de la combustion en lit fluidisé, à l'unité de démonstration de Chatham, ainsi qu'au sujet de certains combustibles appelés Carbogel.

Ces programmes parviendront à maturité et nous verrons ensuite si le secteur privé est disposé à prendre la relève et à poursuivre les travaux. Nous sommes confiants qu'elle le fera en temps et lieu.

Quant à savoir si d'autres programmes ou d'autres activités de ce genre se révèleront nécessaires, vous êtes sans doute au courant que le vice-premier ministre a constitué un groupe de travail particulier afin de discuter avec les premiers ministres de la possibilité d'accroître les débouchés du charbon de l'Ouest en Ontario. Cela a donné lieu à un certain nombre d'initiatives qui sont présentement envisagées par le vice-premier ministre et les premiers ministres. Ils devaient se rencontrer il y a quelques semaines. Malheureusement, la réunion a été annulée en raison de circonstances imprévues. Nous nous attendons à ce qu'une décision soit prise sous peu dans ce domaine.

M. MacLellan: Le groupe du vice-premier ministre s'arrête aux questions à long terme, mais je me concentre sur le fait que certaines sommes ont été dépensées pour ces deux programmes, la combustion en lit fluidisé et le combustible charbon-eau. Vous dites qu'il incombe désormais au secteur privé à prendre la relève. A-t-on fait mine de prendre la relève? Dans les deux cas, le gouvernement a-t-il atteint un degré de réalisation qui puisse encourager le secteur privé à prendre la relève?

M. Merrithew: Le programme d'utilisation du charbon a coûté en tout 78$ millions, dont 37.8$ millions pour les

[*Text*]

in the Miramichi. There was a shortfall of money of $6 million, which was picked up this year by Treasury Board. I can tell you that the technologies that have been developed there are being used and examined by people from around the world. That does not mean—you are absolutely right—that we should not try to follow up with other kinds of projects—for example, Carbogel—that might be of use to the sector. Particularly it could be the high sulphur coal as we have, you and I—particularly I in Atlantic Canada.

With regard to the western coal to Ontario, I can tell you that our deputy prime minister has been in touch with the four premiers on the intergovernmental report that was passed out to them in January 1988. I think they have arrived at a decision on that. I do not know whether an announcement has been made or a final decision been made, but they were positive towards the recommendations in the report. I can tell you further that there are R and D funds within those expenditures.

Mr. MacLellan: Yes, but are further funds going to be spent on these projects? If you were to tell me that you did not think the projects were worth further funds then that would be an answer too, but what I want to know is this. Considerable funds are being spent on both of these projects. How successful are they? Where do they stand now? Where are they vis-à-vis similar projects in other countries? Where have we brought these two projects to, and are they viable? How do they relate, for instance, to the Carbogel project? How do they relate, for instance, to the synfuels project that was being talked about for the Strait of Canso? We have these projects. We have money spent on them. There is a lot of expectation created in Atlantic Canada, particularly in my area, about these projects, or at least one of them, breaking through to increase the utilization of coal and increasing the environmental levels. Where do we stand now on all this activity?

• 1610

Dr. Perron: Madam Chairman, with your permission, I would like to call on Mrs. Nancy Mitchell, who is the manager of the Coal Division at EMR and has supervised the whole program from its inception, to deal with your detailed questions.

Ms Nancy Mitchell (Director, Coal Division, Mineral and Metal Commodities Branch, EMR): I just wanted to let you know about some exciting developments happening on the cold-water fuel side as a result of the program on which we spent quite a fair bit of time and money in the last four or five years.

There are two projects now under way. One is with the pulp and power company within Nova Scotia, to actually use cold-water fuel to fire their boilers for steam for industrial processing. The second one, which is probably

[*Translation*]

travaux à Miramichi. Il a fallu quelques 6$ millions en plus, que le Conseil du Trésor a autorisés cette année. Je puis vous dire que la technologie qui a été mise au point à ces deux endroits a eu des preneurs un peu partout dans le monde. Ce n'est pas dire—vous avez parfaitement raison—que nous ne devrions pas tenter d'y donner suite en prévoyant d'autres travaux—par exemple, Carbogel—dont le secteur pourrait bénéficier. En particulier, il y a le charbon à haute teneur en soufre que nous trouvons, vous et moi—surtout moi, dans le Canada Atlantique.

Pour ce qui est des débouchés du charbon de l'Ouest en Ontario, je peux vous dire que notre vice-premier ministre a pris contact avec les quatre premiers ministres, dès que le rapport inter-gouvernemental leur a été transmis en janvier de 1988. Je crois qu'ils en sont venus à une décision à ce propos. J'ignore si on l'a rendue publique ou si une décision finale a été prise, mais leur attitude à l'égard des recommandations figurant dans ce rapport était positive. Je peux vous dire en outre que ces dépenses comprennent des fonds octroyés à la recherche et au développement.

M. MacLellan: Oui, mais va-t-on octroyer d'autres fonds à ces programmes? Si vous me disiez que l'on a jugé bon de ne pas attribuer d'autres fonds à ces programmes, ce serait aussi répondre à ma question, mais voici ce que je veux savoir. On a attribué des sommes considérables à ces deux programmes. Ces derniers ont-ils été fructueux? Où en sommes-nous maintenant? Comment se comparent-ils à des réalisations analogues dans d'autres pays? Où en sont ces programmes et sont-ils viables? Ainsi, dans quelle mesure se rattachent-ils au programme Carbogel? Ainsi, comment se rattachent-ils au programme de combustible synthétique dont on a parlé pour la région du Détroit de Canso? Nous avons réalisé ces programmes, auxquels nous avons attribué une certaine somme. On a suscité beaucoup d'espoir dans les provinces atlantiques, notamment dans ma région, lorsque ces programmes, ou du moins l'un d'entre eux, ont été mis en oeuvre, car on y voyait une percée pour ce qui est d'accroître l'usage du charbon tout en assainissant l'environnement. Où en sont ces programmes?

M. Perron: Madame la présidente, avec votre permission, je vais demander à M^me^ Nancy Mitchell, chef de la division du charbon au ministère, qui a supervisé tout le programme depuis sa mise en route, de vous fournir des détails à ce propos.

Mme Nancy Mitchell (directrice, division du charbon, direction des minéraux et des métaux, EMRC): J'aimerais vous dire qu'en matière du combustible charbon-eau, le programme auquel nous avons consacré beaucoup de temps et d'argent depuis quatre ou cinq ans a donné lieu à des suites fascinantes.

Deux projets ont vu le jour. Premièrement, un fabricant de pâtes et papier de la Nouvelle-Écosse envisage effectivement d'utiliser le combustible charbon-eau pour alimenter ses chaudières à vapeur dans ses ateliers de

[*Texte*]

more dramatic, and has more long-term impacts, on which my staff are working with the Nova Scotia Power Corporation and Cape Breton Development Corporation, is to look at the potential for cold-water fuel in Nova Scotia Power's oil-fired boilers on a permanent basis.

Both Cape Breton Development Corporation and Nova Scotia Power Corporation, if you can call them the private sector in Nova Scotia, are actively involved in putting some of their own time, effort and money into that particular project. I think it has a great future.

Mr. MacLellan: I am not really getting the information. I just want to know where all the activity so far has brought us. Are we any further ahead, or are we starting out all over again with more pilot projects?

Mr. Gustafson: Thank you, Mr. Minister, for your report. The questions I have are probably quite regional to the constituency I serve. You mentioned the coal and the good work the deputy leaders have been doing on this between the provinces in the west and Ontario. What is this going to mean for Saskatchewan?

I have my colleagues from Alberta sitting beside me. I think they probably represent about 60% to 70% of coal mining in Canada. Saskatchewan would be a small percentage of this. But we do have lignite coalin the constituency I serve, at Estevan. Is there something positive in this for us in Saskatchewan?

Mr. Merrithew: This is not a new issue, Madam Chairperson, and your point is well taken. The unfortunate part of our coal is we have probably 5,000 times as much as we need of excellent, low-sulphur coal, but in the wrong part of Canada, away from the actual users, the consumers. The largest user would of course be Ontario Hydro.

To address this issue—and I have been working with them, as has Mr. Mazankowski, for a long time—we set up this interdepartmental task force, which did report on the issue. Aside from actually finding a way to subsidize transportation, what else can we do to make sure we meet as many of the restraints, to get the coal in the most efficient way from where it is now, essentially in British Columbia, Alberta and Saskatchewan, to the main user, who happens to be in central Canada?

There was an action committee set up, composed of Mr. Mazankowski, and of course your premier and the premiers of Alberta and Ontario. I can tell you they were discussing the issue today.

Dr. Perron: Discussions are still going on.

[*Traduction*]

transformation. Deuxièmement, ce qui est encore plus frappant, vu sa répercussion à long terme, et ce à quoi mon personnel collabore avec la Nova Scotia Power Corporation et la Société de développement du Cap Breton, c'est la possibilité d'utiliser en permanence le combustible charbon-eau dans les chaudières à mazout de Nova Scotia Power.

Tant la Société de développement du Cap Breton que la Nova Scotia Power Corporation, que l'on peut, à la rigueur, ranger dans le secteur privé en Nouvelle-Écosse, ont eux-mêmes consacré leur temps, leurs efforts et leurs capitaux à la réalisation d'un tel projet. Je crois qu'il s'agit d'une innovation appelée à un grand avenir.

M. MacLellan: Ce n'est pas vraiment la réponse que je recherchais. J'aimerais savoir où nous en sommes grâce à cette activité. Avons-nous progressé, ou bien va-t-on reprendre à zéro avec d'autres projets pilotes?

M. Gustafson: Merci, monsieur le ministre, de votre exposé. Les questions que je vais poser ont probablement trait à la circonscription que je dessers. Vous avez parlé du charbon et du bon travail que les vice-premiers ministres et les premiers ministres de l'Ouest et de l'Ontario ont accompli à cet égard. Qu'est-ce que cela va signifier pour la Saskatchewan?

J'ai des collègues de l'Alberta à mes côtés. Je crois que cette province répond probablement pour 60 ou 70 p. 100 de l'exploitation houillère au Canada. La Saskatchewan n'en représente qu'un faible pourcentage. On trouve toutefois du lignite dans ma circonscription, à Estevan. Y aurait-il quelque chose de positif pour nous en Saskatchewan?

M. Merrithew: La question n'est pas nouvelle, madame la présidente, mais votre remarque est tout à fait valable. Ce qui est regrettable, à l'égard du charbon, c'est que nous en avons probablement 5,000 fois trop, sous forme de charbon à faible teneur en soufre, chose excellente, mais il est mal situé au Canada, loin des usagers, loin des consommateurs. Le plus important consommateur serait, bien sûr, l'Hydro Ontario.

À cette fin—et il y a longtemps que je leur en parle, tout comme M. Mazankowski—nous avons constitué un groupe de travail interministériel, qui nous a ensuite remis son rapport. À moins d'établir un mode de transport subventionné, quoi d'autre pourrions-nous faire pour nous assurer que nous répondons au plus grand nombre de conditions possible, que nous faisons parvenir le charbon le plus efficacement possible, à partir de l'endroit où il est extrait, notamment en Colombie-Britannique, en Alberta et en Saskatchewan, vers les principaux consommateurs, qui se trouvent être au Canada central?

Un comité d'action s'est constitué, qui comprenait M. Mazankowski et, bien sûr, votre premier ministre et ceux de l'Alberta et de l'Ontario. Je peux vous dire qu'ils discutent de cette question en ce moment.

M. Perron: Ces entretiens se poursuivent.

[*Text*]

Mr. Merrithew: I think there is a large measure of unanimity in meeting the recommendations passed to them. We will undoubtedly hear more about this soon. Your point is well taken. We want to do as much as we can to utilize that coal, which is definitely underutilized now.

Mr. Gustafson: What about the pollution factor of that western coal, particularly the lignite as compared to the harder coals? Is there something positive about this?

Ms N. Mitchell: This is in answer to your first question as well. One of the projects identified under the western coal to Ontario report by the secretariat did deal with what was called low-rank coal upgrading, which is what we in fact consider lignite and the subituminous coals in Alberta. Even though the premiers and the deputy prime minister have not formally said they want to move ahead with that report, we already have a committee in place with the Province of Saskatchewan and people within Energy, Mines and Resources and the industry to look at what technologies can be used to upgrade coals like lignite and use them as a potential substitute for natural gas, for example, in the industrial area in Saskatchewan. It is an area the province is quite keen on working in, and we are really interested in working along with them.

• 1615

In answer to your second question, like the rest of western Canadian coals, lignite is very low in sulphur. It is in about the 0.2% or 0.3% range as opposed to eastern Canada where it is more in the 3% or 4% range. It is a very high benefit.

Mr. Gustafson: I have another question which I guess would be regional, and that is with regard to potash. Saskatchewan faces some major problems with potash and with exports to the United States, which of course are very important, and very important to the whole trade agreement that we are looking forward to, at least on this side of the House. Do you have any update on what is happening in the potash mines in terms of production, especially to the United States because I understand that is where our market is?

Mr. Merrithew: That is a most interesting issue that took place last year when two marginal producers in New Mexico persuaded the United States government to institute an anti-dumping claim against Canada. I have dealt and met with on many occasions the potash producers on this particular trade action. Both New Brunswick and Saskatchewan potash producers wish to undertake to deal with that themselves, and rightly so, because it was anti-dumping. I can tell you the first thing they did was of course to markedly increase the price per tonne of potash. That price stuck domestically and internationally, and interestingly the anti-dumping case was not proved against them.

[*Translation*]

M. Merrithew: Je crois que les recommandations ont recueilli à peu près tous les suffrages. Nul doute que nous aurons bientôt des nouvelles à ce sujet. Votre observation est tout à fait valable. Nous cherchons le plus possible à utiliser ces charbons, car il s'en fait un bien piètre usage en ce moment.

M. Gustafson: Et la pollution attribuée au charbon de l'Ouest, notamment au lignite par rapport au charbon plus dur? Y a-t-il quelque chose de positif à ce sujet?

Mme N. Mitchell: Voilà qui va répondre tout aussi bien à votre premier question. Dans le rapport concernant les débouchés du charbon de l'Ouest en Ontario, le secrétariat a fait allusion à un projet, soit la valorisation du charbon de faible qualité, parmi lequel sont rangés les lignites et les charbons subitumineux de l'Alberta. Quoique les premiers ministres et le vice-premier ministre n'aient pas déclaré officiellement qu'ils veulent donner suite à ce rapport, un comité s'est constitué, composé de représentants de la Saskatchewan et de fonctionnaires d'Énergie, Mines et Ressources Canada et de représentants de l'industrie, pour déterminer à quelles technologies on pourrait avoir recours afin de valoriser des charbons tels le lignite, avec la possibilité de les substituer au gaz naturel, par exemple, dans les zones industrielles de la Saskatchewan. Ces dernières intéressent particulièrement la province, et nous sommes entièrement disposés à lui offrir notre collaboration.

En réponse à votre deuxième question, je dirais que le lignite, tout comme les autres charbons de l'ouest canadien, comporte très peu de soufre, soit 0,2 ou 0,3 p. 100, alors que les charbons de l'Est en comportent 3 ou 4 p. 100. Voilà l'avantage qu'offrent les premiers.

M. Gustafson: J'ai une autre question, qui intéresse aussi ma région, mais cette fois au sujet de la potasse. La Saskatchewan éprouve en ce moment des difficultés majeures avec la potasse et avec ses exportations vers les États-Unis, questions fort importantes, certes, particulièrement pour l'Accord de libre-échange qui est envisagé, du moins de notre côté à la Chambre. Auriez-vous des renseignements à jour concernant notre production de potasse, et surtout notre situation vis-à-vis des États-Unis, où se touvent nos débouchés, je crois?

M. Merrithew: La question est devenue d'actualité l'an dernier, lorsque deux producteurs marginaux du Nouveau-Mexique ont convaincu le gouvernement américain de porter plainte contre le Canada sous prétexte que ce dernier faisait du dumping. Suite à cette plainte, j'ai eu maintes fois l'occasion de rencontrer nos producteurs de potasse. Tant ceux du Nouveau-Brunswick que de la Saskatchewan ont exprimé le désir de s'en occuper eux-mêmes, à juste titre, étant donné qu'il s'agissait d'antidumping. Je peux vous dire que la première chose qu'ils ont fait, bien entendu, c'est d'augmenter sensiblement le prix de la potasse à la tonne. Ces hausses de prix se sont appliquées tant au Canada qu'à l'échelle

[*Texte*]

As a result the farmers in the United States are now paying markedly increased prices for potash, and therefore their fertilizers will be more expensive. Maybe I should not be critical of another country, but it shows that when we become too protectionist and undertake to protect marginal mines like that, who pays? The consumer in the United States is paying, and meanwhile—I think this should have happened anyway—the prices are up. I think they are probably about 70% of capacity. With increased prices and increased production, things are looking much brighter than they did a few years ago.

Mr. Gustafson: Will the free trade agreement solve some of these problems in an ongoing sense?

Mr. Merrithew: Yes. As part of the program we had this morning on the Mineral Outlook Conference, Mr. Bob Herztein, a lawyer and an American, portrayed our mining industry and made a comparison with what happened with the lumber issue. He took the case back to the 1983 countervailing duty issue, and the 1985-86 one, and I happened to be caught up in both. He showed what happened in 1983, in which Canada was perceived to have won, and he showed what happened in 1986, which was resolved out of the court system. He showed what free trade will do for you, and he outlined three major dispute mechanism sections in the agreement that would help. This is an American lawyer, and he said we will be far better off with this free trade agreement than we would if we did not have it, as we did not have it when we made the decision in December 1986.

Mr. Gustafson: I have one more question, and it relates to the uranium mining in Saskatchewan. I would like to know something about the deposits in terms of volume. What is the size of the deposits? What is happening in that industry and what impact have recent events in Europe had on that industry? Do you see it as a developing industry?

• 1620

Mr. Merrithew: There is no question that significant new developments can take place in terms of uranium, both mining and processing. Interestingly you are right; it probably will take place in Saskatchewan. In Cigar Lake you have perhaps one of the richest bodies of uranium in the world.

I have met with potential and real investors in Key Lake and that particular development. We think they have a very bright future. There is a great deal of interest in it from Europe, Japan and South Korea. Only about 2% of our investment in uranium mining is American. It is not an issue for them, despite the fact that the free trade deal helped. We will not get into it now, but it helped the uranium industry there.

[*Traduction*]

internationale, et chose intéressante, la plainte d'antidumping s'est terminée par un non-lieu.

Résultat, les cultivateurs américains paient désormais le gros prix pour la potasse, ce qui a influé sur le prix des engrais. Je ne devrais peut-être pas formuler de reproches envers un autre pays, mais lorsqu'on veut être trop protectionniste, lorsqu'on veut protéger de telles exploitations minières marginales, qui en fait les frais, pensez-vous? C'est le consommateur américain, et entre-temps, je crois que cela aurait eu lieu de toute façon—les prix augmentent. Il est probable que les exploitations minières fonctionnent à quelque 70 p. 100 de leur capacité. Étant donné la hausse des prix et de la production, leur avenir semble beaucoup plus rose qu'il y a quelques années.

M. Gustafson: L'Accord de libre-échange va-t-il permettre de résoudre certains de ces problèmes?

M. Merrithew: Oui. Dans le cadre de la conférence sur les perspectives minières qui s'est tenue ce matin, un avocat américain, M. Bob Herztein, a dépeint la situation de notre industrie minière en la comparant avec ce qui s'était passé dans le secteur du bois d'oeuvre. Il a parlé des droits compensatoires imposés en 1983, puis en 1985 et 1986, et il arrive que j'étais impliqué dans les deux cas. Il a rappelé les événements de 1983, où le Canada est apparemment sorti gagnant, ainsi que ceux de 1986, où la question a été tranchée sans passer par les tribunaux. Il a mis en lumière les avantages du libre-échange, en appuyant sur les trois articles qui ont trait au mécanisme de règlement des différends. C'est un avocat américain qui a dit: l'Accord de libre-échange est tout à notre avantage, et il suffit pour s'en rendre compte de s'en remettre à la décision prise en décembre 1986.

M. Gustafson: J'ai une dernière question, qui a trait à l'extraction de l'uranium en Saskatchewan. J'aimerais être mieux renseigné au sujet de la valeur des gisements. Quelle est l'ampleur de ces gisements? Que se passe-t-il dans cette industrie et quelle incidence les événements récemment survenus en Europe ont-ils eu sur elle?

M. Merrithew: Il est évident qu'on pourrait voir de nouvelles découvertes très importantes dans les domaines de l'exploitation et du traitement de l'uranium. Vous avez tout à fait raison de dire que cela va sans doute se faire en Saskatchewan. On trouve à Cigar Lake l'une des réserves d'uranium qui compte parmi les plus riches au monde.

J'ai rencontré des investisseurs et des investisseurs potentiels qui s'intéressent au projet de Key Lake. Nous pensons que ce projet a un excellent avenir. Les Européens, les Japonais et les Sud-Coréens s'y intéressent beaucoup. Seuls 2 p. 100 environ des investissements dans l'exploitation de l'uranium au Canada sont Américains. Ce n'est pas une grosse affaire pour les Américains, même si l'accord de libre-échange a aidé. Nous n'allons pas nous lancer dans une discussion là-dessus maintenant, mais je

[*Text*]

I could ask somebody to go into perhaps a bit more detail for your edification. I think it is a very bright new opportutnity in Saskatchewan.

Dr. Perron: Madame Chairperson and Mr. Minister, the development in Saskatchewan will take place on many fronts. There is a lot of activity on many properties and there is also some interest for some properties in the Northwest Territories. By and large these developments will take place with very significant foreign investment, as the minister indicated, European in the main part with some Japanese and Korean contributions. The free trade agreement would protect the Canadian market of over $350 million in the U.S. As the market expands in the coming decades, you will see these projects come on stream. There is no doubt that very few countries in the world can compete with us.

It has been said that Saskatchewan is the Saudi Arabia of uranium. I believe it is borne out by all the facts we have so far.

Mr. Parry: I would like to welcome the minister to the committee. I was somewhat amused by the initial stage of your presentation. You stated that MESP activities involve all parts of the country from east to west, from the very top of Canada to the 49th Parallel. I wondered if the computer mapping that you have been promoting and glorifying has somehow eliminated all of Canada south of the 49th Parallel. It takes in most of our population and a considerable portion of our mining activities. I would accept it if you said that it was indicative of a very strong western orientation. I am sure my colleages would also.

On the mineral development agreements you mention on page 6, you say that your department administers these MDAs, which have a total commitment of $143 million—

Mr. Merrithew: That is over a five-year period.

Mr. Parry: We are basically talking about federal commitment in the region of $28.6 million per year for five years.

Mr. Merrithew: Yes.

Mr. Parry: Are they all phased similarly?

Mr. Merrithew: No. Five expire in 1988-89 and another four expire in 1988-89-90. There are two in the Northwest Territories in 1991 and in the Yukon in 1990.

[*Translation*]

peux néanmoins dire que cela aura aidé l'industrie de l'uranium là-bas.

Si vous le voulez, un de mes collaborateurs pourrait peut-être vous fournir des renseignements supplémentaires là-dessus. Quoi qu'il en soit, je pense que c'est une merveilleuse occasion pour la Saskatchewan.

M. Perron: Madame la présidente, monsieur le ministre, le travail dans ce domaine en Saskatchewan sera mené sur plusieurs fronts. Il y a beaucoup d'activités à divers endroits et l'on s'intéresse également à certains terrains dans les Territoires du Nord-Ouest. De façon générale, ces projets seront entrepris avec des investissements étrangers massifs, et, comme l'a dit le ministre, les principaux participants seront Européens, Japonais et Coréens. Quant à l'entente de libre-échange, celle-ci protégerait le marché canadien qui compte pour plus de 350 millions de dollars aux États-Unis. Ces différents projets seront lancés au fur et à mesure que le marché s'élargira au cours des décennies à venir. Il est clair que très peu de pays pourront nous faire concurrence sur ce plan.

Il a déjà été dit que la Saskatchewan et l'Arabie Saoudite de l'uranium, et je pense que tous les faits que nous avons pu recueillir jusqu'ici iraient dans ce sens.

M. Parry: J'aimerais souhaiter la bienvenue au ministre devant le Comité. J'ai été quelque peu amusé par ce que vous avez dit au début de votre exposé. Vous avez déclaré que les activités entreprises en vertu du Programme des minéraux et des sciences de la terre visent toutes les régions du Canada, d'est en ouest et du nord du pays jusqu'au 49^{e} parallèle. Je me suis demandé si le service de cartographie informatisé dont vous ne cessez de faire la promotion et de chanter les louanges a je ne sais trop comment éliminé toute la partie du Canada située au sud du 49^{e} parallèle. Cette bande compte le gros de la population et une part importante de nos activités minières. Je serais cependant prêt à accepter cela si vous disiez que c'était indicatif d'une orientation très fortement axée sur l'Ouest, et je suis certain que ce serait également le cas de mes collègues.

Pour ce qui est des ententes sur l'exploitation minérale dont vous parlez à la page 7, vous dites que ces ententes, pour lesquelles vous avez prévu l'affectation de 143 millions de dollars. . .

M. Merrithew: Sur une période de cinq ans.

M. Parry: Il est donc question d'un engagement fédéral de l'ordre de 28,6 millions de dollars par an, sur cinq ans, n'est-ce pas?

M. Merrithew: Oui.

M. Parry: Et ces ententes sont-elles toutes échelonnées de la même façon?

M. Merrithew: Non. Il y en a cinq qui expirent en 1988-1989 et quatre autres qui expirent en 1988-1989-1990. Il y en a encore deux qui concernent les Territoires du Nord-Ouest qui vont arriver à terme en

[*Texte*]

Mr. Parry: We are looking at something in the range of $28 million to $30 million per year as the federal government's contribution?

Dr. Perron: That is correct.

Mr. Parry: Also on page 6, could you clarify "reactive acid mine tailings"?

Dr. M.D. Everell (Assistant Deputy Minister, Mineral and Energy Technology Sector, Department of Energy, Mines and Resources): This is the type of tailing that we get mainly from the exploitation of deposits of sulphite, like copper, lead or zinc sulphite.

• 1625

After the treatment of the ore, tailings are produced. The ideal really is to find better ways to manage these tailings in the future, because estimations right now give us the impression that in the next 10 years we could end up spending maybe $1 billion to $2 billion just to manage the tailings produced by our sulphide mines. So especially CANMET, but in collaboration with industry and the provinces, is putting together a program right now to try to improve the situation by reducing the cost of tailings management for industry. In fact, also some of the tailings belong to the Crown, so we are working for the Crown as well as industry.

Mr. Parry: Also in your opening statement, I think mention was made of extracting remaining values from tailings. But I take it that those would not be the sulphide tailings, that we are talking about gold tailings principally.

Dr. Everell: Absolutely.

Mr. Parry: Is there any research presently being funded or undertaken into heap leaching, bacterial leaching, those sorts of methods?

Dr. Everell: Yes, I would say that in general CANMET is quite involved in looking at heap leaching, but in the end in must be done by industry. A number of projects have taken place in Canada. Of course, Canada is not as well endowed regarding the weather as is the southern United States, so it is a bit more difficult in Canada to do heap leaching. Some projects are being started or have been done at the pilot level, but the process is still under development. Which was your. . .?

Mr. Parry: Bacterial leaching.

Dr. Everell: Of course, the best example we have there is with Denison. The bacteria are hard at work. They are trying to extract uranium successfully at Denison. Bacteria are also being used and applied by CANMET these days to clean some environmental problems. Some

[*Traduction*]

1991 et encore une autre, celle-ci pour le Yukon, qui expirera en 1990.

M. Parry: La contribution du gouvernement fédéral serait donc de l'ordre de 28 à 30 millions de dollars par an, n'est-ce pas?

M. Perron: C'est exact.

M. Parry: Vous parlez par ailleurs à la page 8 de votre mémoire de «résidus miniers acides réactifs». Pourriez-vous m'expliquer de quoi il s'agit?

M. M.D. Everell (sous-ministre adjoint du Secteur de la technologie des minéraux et de l'énergie, ministère de l'Énergie, des Mines et des Ressources): Il s'agit du genre de résidus qui proviennent de l'exploitation de dépôts de sulfate, notamment le sulfate de cuivre, de plomb ou de zinc.

Le traitement du minerai produit des résidus. L'idéal serait de trouver de meilleurs moyens d'utiliser ces résidus, car d'après les prévisions qu ont été faites nous devrons dépenser au cours des 10 prochaines années 1 à 2 milliards de dollars sur la simple gestion des résidus produits par nos mines de sulfate. C'est pourquoi CANMET, en collaboration avec l'industrie et les provinces, est en train de mettre au point un programme visant à améliorer la situation en réduisant le coût de la gestion des résidus pour l'industrie. D'ailleurs, certains de ces résidus appartiennent à la Couronne et nous travaillons donc autant pour la Couronne que pour l'industrie.

M. Parry: Il me semble que vous avez également parlé dans votre déclaration de la question d'essayer d'extraire quelque chose des résidus. Mais j'imagine que vous ne vouliez pas parler là des résidus de sulfate, mais surtout des résidus d'or.

M. Everell: Exactement.

M. Parry: Avez-vous financé ou entrepris des travaux de recherche sur la lixiviation en tas, sur la lixiviation bactérienne ou sur d'autres méthodes du genre?

M. Everell: Oui, CANMET est en train d'étudier la lixiviation en tas, mais au bout du compte, il faudra que ce soit fait par l'industrie. Plusieurs projets ont été entrepris au Canada. Le problème, bien sûr, c'est que le Canada n'est pas aussi gâté, côté conditions météorologiques, que le sud des États-Unis, et il est donc un peu plus difficile de faire chez nous de la lixiviation en tas. Certains projets ont été lancés ou entrepris à titre d'essais, mais le processus n'est pas encore tout à fait au point. Quel était votre. . .?

M. Parry: La lixiviation bactérienne.

M. Everell: Bien sûr, le meilleur exemple que nous en avons est du côté de Denison. Les bactéries travaillent très fort. On essaie d'extraire de l'uranium à Denison. On utilise également des bactéries ces jours-ci à CANMET en vue de régler certains problèmes environnementaux.

[*Text*]

bacteria have a taste for heavy metals, so we try to domesticate these things to work for us. In fact, we have one of the best groups in Canada working in CANMET, totally with industry, trying to apply what could be high-tech work to a basic industry like mining, and successfully.

Mr. Parry: I am aware that EMR has spent some money on fuel alcohols. Does that basically come under the energy section? Are we straying into the energy side of the operation there?

Dr. Everell: Yes, you are right. It is managed by the Energy Commodity Sector of our department.

Mr. Parry: That, of course, would lap into your responsibilities with regards to forestry as well, would it not, Gerry? Perhaps following up on that, is the fluidized bed combustion project simply on coal or is it also looking at burning wood on fluidized bed?

Ms N. Mitchell: At the moment, the unit at Chatham is on coal, but it was intended to be capable actually to burn wood as well. In fact, that is one of the benefits of fluidized bed, because it can provide a capability to burn all kinds and varieties and grades of fuels, from wood to all kinds of coals to maybe even rubber tires.

The unit at Summerside, which is another small fluidized bed, also burns coal, and I know the base is quite interested in testing out wood in that unit as well. It requires some additional capital facilities in terms of other handling equipment to handle the wood in addition to the coal.

Mr. Parry: So back with fluidized bed and also the cold water project, is there any commercial value to the energy? Is it being marketed in any way? Is there an intention to turn these over to some private energy company for commercial use in the future?

• 1630

Ms N. Mitchell: The unit at Chatham has now been turned over to the New Brunswick Electric Power Commission. They are continuing to operate it, and will continue to do so, both to produce electricity and as well as to undertake some additional testing of coals.

Mr. Parry: So it is part of their base-load capacity now.

Ms N. Mitchell: Absolutely. Well, peak load and then base load.

Mr. Parry: They are using it for peak load.

[*Translation*]

Certaines bactéries ont un goût prononcé pour les métaux lourds et nous essayons de les apprivoiser pour qu'elles nous rendent service. D'ailleurs, nous avons chez CANMET l'une des meilleurs équipes du pays et au côté de l'industrie, elle essaie d'apporter une technologie de pointe à l'industrie de base qu'est l'exploitation minière, et elle réussit assez bien.

M. Parry: Je sais que le ministère de l'Énergie, des Mines et des Ressources a consacré certains fonds aux alcools carburants. Cela relève-t-il du secteur énergétique? S'agit-il là de quelque chose qui relève plutôt du côté énergie des activités du ministère?

M. Everell: Oui. Cela relève du secteur des ressources énergétiques du ministère.

M. Parry: Et cela chevaucherait bien sûr vos responsabilités en matière de foresterie, n'est-ce pas? Et, toujours dans le même ordre d'idées, le projet de combustion en lit fluidisé vise-t-il uniquement le charbon ou bien allez-vous également vous pencher sur la combustion de bois sur lit fluidisé?

Mme N. Mitchell: À l'heure actuelle, l'unité à Chatham n'utilise que le charbon, mais elle a été construite en vue de pouvoir brûler également du bois. D'ailleurs, c'est là l'un des avantages de la combustion en lit fluidisé, car ce processus permet de brûler toutes sortes de catégories de combustibles, qu'il s'agisse de bois ou de différentes qualités de charbon, et l'on pourrait peut-être même utiliser des pneus en caoutchouc.

Quant à l'unité de Summerside, une autre petite unité de combustion en lit fluidisé, celle-ci brûle elle aussi du charbon, et je sais qu'on a envie de voir là-bas aussi ce que cela donnerait avec le bois. Il faudrait cependant faire certains investissements car il faudrait disposer de matériel différent pour pouvoir traiter et le bois et le charbon.

M. Parry: Pour ce qui est de la combustion en lit fluidisé et du projet charbon-eau, l'énergie produite a-t-elle une valeur commerciale? Va-t-on la commercialiser d'une façon ou d'une autre? Compte-t-on céder un jour tout cela à une centrale privée pour qu'elle puisse en faire une utilisation commerciale?

Mme N. Mitchell: L'unité à Chatham a été cédée à la New Brunswick Electric Power Commission. Celle-ci l'exploitera en vue de produire de l'électricité et elle compte également faire de nouveaux essais avec du charbon.

M. Parry: Cette unité fait donc partie de sa capacité de base.

Mme N. Mitchell: Absolument. Ou plutôt sa capacité de pointe et sa capacité de base.

M. Parry: Elle s'en sert pour satisfaire la demande en période de pointe.

[*Texte*]

Ms N. Mitchell: Yes. One of the reasons we did the demonstration project for both utilities was the Nova Scotia Power Corporation were looking at that as their next generation unit, probably for the early 1990s, about 1992, because of its capacity to reduce sulphur by about 90%.

Mr. Parry: And Charlottetown?

Ms N. Mitchell: Charlottetown is a cold-water fuel demonstration. Our particular demonstration is complete now, but CANMET will be using that facility in the summer to continue getting the few remaining bugs out of their own design for a burner which can be used to burn cold-water fuel. CANMET, in conjunction with NRC, have probably developed the world's finest burner to be able to use that fuel. Since it is very abrasive, it needs something like ceramics to be able to burn it properly.

I think in our cold-water fuel and in our fluidized bed combustion we probably have done a lot in terms of putting Canada in the forefront of these new technologies. There is a lot of potential for them to be commercially used in the Maritimes.

Mr. Parry: The processing—smelting, fabrication—of mineral products is an area that concerns me, particularly since there is a fair amount of mining in the area that I represent. Can we point to any significant developments in the last year or so, not only in terms of technology but in terms of processing in Canada?

Dr. Everell: If you want to talk about technology, of course I am the right person, since I am responsible for CANMET. As you may know, a lot of new technology is being developed at CANMET to better process our resources.

You may have read in the last few months that presently we are quite involved with the Iron Ore Company of Canada in trying to extract additional metal values from tailings. This is one way to get more out of our resources. Of course at the same time, CANMET is involved with other companies to develop cleaner processes. Processing of ores, especially with pyrometallurgy, is subject to a lot of potential pollution problems. So we are involved in this, with a certain number of companies, to reduce, for instance, the possibility of producing additional sulphur in the air with certain treatment processes for sulphide ores.

[*Traduction*]

Mme N. Mitchell: Oui. L'une des raisons pour lesquelles nous avons entrepris ce projet de démonstration pour les deux services d'utilité publique est que la Nova Scotia Power Corporation pensait pouvoir s'en servir comme unité de la génération suivante, sans doute aux environs de l'année 1992, et ce à cause de sa capacité de réduire le soufre d'environ 90 p. 100.

M. Parry: Et Charlottetown?

Mme N. Mitchell: L'unité de Charlottetown est une unité de démonstration pour l'utilisation de charbon-eau. La démonstration en tant que telle est terminée, mais CANMET se servira de ces installations pendant l'été dans l'espoir de trouver une solution aux derniers hics de son propre modèle de brûleur qui peut être utilisé pour brûler le combustible charbon-eau. CANMET conjointement avec le Conseil national de recherche, a sans doute mis au point le meilleur brûleur au monde qui peut être utilisé pour ce combustible. Étant donné que c'est très abrasif, il faut utiliser une matière comme la céramique pour que la combustion se fasse bien.

Je pense qu'en ce qui concerne la technologie charbon-eau et celle de la combustion en lit fluidisé, nous avons fait beaucoup pour que le Canada soit en première ligne pour ce qui est de ces nouvelles technologies. Il existe un grand nombre d'utilisations commerciales potentielles qu'on pourrait en faire dans les Maritimes.

M. Parry: Le traitement—c'est-à-dire la fusion et la fabrication—de produits minéraux est une question qui m'intéresse beaucoup étant donné surtout que l'exploitation minière est une activité importante dans la région que je représente. Pourriez-vous me donner des exemples de nouvelles percées qui auront été faites au cours de la dernière année du côté non seulement de la technologie, mais également du traitement tel que cela se pratique ici au Canada?

M. Everell: Si vous voulez parler de technologie, c'est à moi qu'il vous faut en effet vous adresser, car je suis responsable de CANMET. Comme vous le savez peut-être, c'est CANMET qui élabore un grand nombre des nouvelles technologies sur lesquelles nous misons pour mieux traiter nos ressources.

Vous aurez peut-être pu lire dans la Presse ces derniers mois que nous travaillons aux côtés de la Iron Ore Company of Canada en vue d'extraire encore d'autres ressources métallurgiques des résidus. C'est là une façon de mieux mettre en valeur nos ressources. En même temps, CANMET participe aux côtés d'autres compagnies à l'élaboration de procédés plus propres. Le traitement des minerais, et je songe ici tout particulièrement à la pyrométallurgie, pose un grand nombre de problèmes de pollution potentiels. C'est pourquoi nous avons entrepris, avec un certain nombre de sociétés, d'essayer de réduire la possibilité de production supplémentaire de soufre dans l'air avec certains procédés de traitement utilisés pour les minerais sulfurés.

[*Text*]

That is a general answer. Many technologies are being approached. But in terms of projects, Mr. Perron will. . .

Dr. Perron: We could add the areas in which we work: deep, underground mining in northern Ontario; developing safer techniques of mining; rock-burst studies that we undertook three years ago now—a very successful program, very useful to allow us to mine at lower depths—new techniques of managing open-pit mines; management of the equipment in open-pit mines to minimize the needless movement of machinery and men in mines; many areas of work involving reduction of polluting emissions in mines such as exhaust fumes from diesel machinery through appropriate filters. A wide variety of initiatives of that nature are now being conducted with the private sector and for which we have private sector partners in order to put the technology into the marketplace.

Mr. Parry: The mineral and metals policy, which was released in May 1987, had as one of its objectives the assisting of workers in communities affected by industrial adjustment. Does your ministry have any responsibility in that area, or is this given to Canada Manpower?

• 1635

Mr. Merrithew: No, the issue has been discussed for many, many years, as you probably know. When I was a provincial minister of mines, it was brought up then. I guess maybe it grew out of the association meeting with mines ministers.

We have received the report. Of course, we now have mechanisms in place by which we can help certain communities in terms of adjustment when they have difficulties like that. You are talking about single-industry towns.

Mr. Parry: Yes.

Mr. Merrithew: Yes, and adjustments when mines close down. In my time in this field, I just detect among industries—and you cannot make a blanket statement because it may not apply to everyone—that when mines are closed for whatever reason, as they inevitably are, there seems to be more of a sympathy or an empathy on the part of an employer to deal with the social consequences of its closing. We know how difficult it is. I think there are new ways of doing this as well. There are definitely fewer mine towns than there used to be, in which they actually would set up a whole community and then have the problem when the ores ran out. However, many of those programs come from other departments like CEIC or Labour.

[*Translation*]

C'est là une réponse générale à votre question. On est en train d'envisager toutes sortes de technologies. Quant au projet en tant que tel, M. Perron pourra. . .

M. Perron: Je pourrais peut-être vous parler des domaines dans lesquels nous travaillons: L'exploitation souterraine à grande profondeur dans le nord de l'Ontario, l'élaboration de techniques d'exploitation minière plus sûres; les études sur l'éclatement de la matière rocheuse que nous avons entreprises il y a maintenant trois ans—et je signalerais que c'est un programme qui a très bien réussi et qui nous aura permis d'exploiter des mines à des profondeurs plus grandes; de nouvelles techniques pour la gestion des mines à ciel ouvert; la gestion du matériel utilisé dans les mines à ciel ouvert pour minimiser le déplacement inutile de machines et d'hommes dans les mines; la réduction des émissions polluantes dans les mines, notamment les gaz d'échappement des appareils diésel, grâce à l'utilisation de filtres appropriés, etc. Une vaste gamme d'initiatives du genre ont été entreprises avec des partenaires du secteur privé en vue de lancer ces nouvelles technologies sur le marché.

M. Parry: L'un des objectifs de la politique sur les minerais et les métaux, diffusé en mai 1987, était d'aider les travailleurs dans les localités touchées par le rajustement industriel. Le ministère que vous dirigez a-t-il une part de responsabilités dans ce domaine ou bien cela relève-t-il uniquement du ministère du Travail?

M. Merrithew: Non, comme vous le savez sans doute, on discute de la question depuis de très nombreuses années. On en parlait déjà alors que j'étais ministre provincial des mines. Cela remonte peut-être à la réunion avec les ministres des mines.

Nous avons reçu le rapport. Sont maintenant bien sûr en place des mécanismes grâce auxquels nous pourrons aider certaines localités lorsqu'elles rencontrent des problèmes du genre. Vous parlez des villes mono-industrielles.

M. Parry: Oui.

M. Merrithew: Il y a des problèmes lorsque les mines ferment. J'ai, quant à moi, constaté parmi les industries—l'on ne peut, bien sûr, pas généraliser, car cela ne s'applique pas forcément à tout le monde—que lorsque les mines ferment quelle qu'en soit la raison, et c'est inévitable—l'employeur semble être plus compatissant et plus compréhensif quant aux conséquences sociales de la fermeture. Nous savons à quel point cela est difficile. Je pense que, là aussi, il y a eu de nouvelles façons de faire. Il y a assurément moins de villes minières que dans le temps, où toute une localité était créée et où il y avait toutes sortes de problèmes dès qu'il n'y avait plus de minerai. Cependant, un grand nombre de ces problèmes relèvent d'autres ministères, comme par exemple celui de l'Emploi et de l'Immigration ou celui du Travail.

[*Texte*]

The Chairman: Mr. Minister, on page 4-50, the Geological Survey of Canada's funding is down from $109.9 million actually spent in the year 1986-87 to $107.4 million in these main estimates. The Atlantic Geoscience Activity has taken the largest cut on a percentage basis. Why is the funding for the Geological Survey of Canada activities going down?

Mr. D.C. Findlay (Director General, Continental Geoscience and Mineral Resources, Department of Energy, Mines and Resources): Madam Chairman, part of the reason for the changes in funding has to do with the profiling of expenditures of a number of external programs that are being conducted by parts of the Geological Survey of Canada, including the Atlantic Geoscience Division. I suspect this is the reason for that particular case.

The Chairman: No, excuse me. I do not understand. It appears here that the Atlantic Geoscience Activity has taken the largest cut on a percentage basis. It is on page 4-50.

Dr. Perron: Madam Chairman, if I may add to that, there are a couple of programs that had a significant impact on the activities of the Atlantic Geoscience Centre. First, the centre was involved in studies offshore related to sovereignty issues. This was a special mandate we had from External Affairs and for which special studies were conducted to ascertain mineral potential or hydrocarbon potential in the various regions under litigation. This had an influence first.

Second, we have a program called the Northern Oil and Gas Action Program or NOGAP, which is a program spearheaded by the Department of Indian Affairs and Northern Development for which we manage part of the research work. Some of the managers or some of the employees were located in the Atlantic Geoscience Centre, and this is where you see this reduction.

I would say on average we have over 30% of our budget on specific sunset programs. There is a fairly complex evolution of programs that are phased in and phased out. We have a constant movement of resources, which is somewhat difficult to track. Basically it is related to the termination of sunset programs that may have an impact on part of the organization, as the case may be.

The Chairman: What is the Capital Acquisition and Replacement Plan?

Dr. Perron: On that subject, Madam Chairman, we are facing a major problem. It is a problem with which EMR and specifically the Mineral and Earth Science Program of EMR has been wrestling for a few years now.

[*Traduction*]

La présidente: Monsieur le ministre je constate, à la page 4-55, que le budget de la Commission géologique du Canada est passé de 109,9 millions de dollars, qui ont véritablement été dépensés—en 1986-1987 à 107,4 millions de dollars. Quant au Centre géoscientifique de l'Atlantique, c'est celui-ci qui a été frappé de la plus forte réduction, en pourcentage. Pourquoi le financement prévu pour les activités de la Commission géologique du Canada a-t-il été réduit?

M. D.C. Findlay (directeur général, direction du continent et des ressources minérales, ministère de l'Energie, des Mines et des Ressources): Madame la présidente, cela est en partie imputable à l'échelonnement des dépenses correspondant à un certain nombre de programmes externes qui ont été entrepris par certains services de la Commission géologique du Canada, notamment la Division géoscientifique de l'Atlantique. J'ai l'impression que c'est à cela qu'est dû cette différence dans ce cas-ci.

La présidente: Excusez-moi, mais je ne comprends pas. Il semble que ce soit l'activité géoscientifique de l'Atlantique qui a été frappée par la plus grosse réduction en pourcentage. Cela figure à la page 4-55.

M. Perron: Madame la présidente, si vous me permettez d'ajouter quelque chose, il y a un certain nombre de programmes qui ont eu une très forte incidence sur les activités du Centre géoscientifique de l'Atlantique. Premièrement, le Centre a participé à des études, au large des côtes, se rapportant à des questions de souveraineté. Il s'agit là d'un mandat spécial qui lui a été donné par le ministère des Affaires extérieures et dans le cadre duquel un certain nombre d'études ont été entreprises en vue de vérifier le potentiel des différentes régions en litige en matière de minerais et d'hydrocarbures. Voilà pour la première chose.

Deuxièmement, nous avons un programme intitulé Programme d'initiative pétrolière et gazière dans le Nord ou PIPGN, qui a été lancé par le ministère de Affaires indiennes du Nord mais dont nous gérons l'aspect recherche. Certains des gestionnaires ou employés se trouvaient au Centre géoscientifique de l'Atlantique, et c'est ce qui explique cette réduction.

Je dirais qu'en moyenne 30 p. 100 de notre budget correspond à des programmes temporisés. Il s'agit d'une suite assez complexe de programmes qui démarrent et qui se terminent à des moments différents. Il y a sans cesse des ressources qui sont déplacées par ci par là, et c'est assez difficile de suivre ce qui se passe. L'expiration de certains programmes temporisés peuvent avoir une incidence sur certaines activités de l'organisation.

La présidente: Qu'est-ce que le plan d'achat et de remplacement des biens d'équipement?

M. Perron: Dans ce domaine, madame la présidente, nous nous trouvons confrontés à un grave problème. Il s'agit d'un problème qui mobilise depuis plusieurs années déjà le ministère de l'Energie, des Mines et des ressources

[*Text*]

Following the economic statement of November 1984, there has been a significant cutback in the budget of EMR. Most of the impact has been borne—as was explained by Minister Masse, I believe, when we last met you—by the Energy Program of EMR. However, there was some spill over because some of these activities were carried out in part by the mineral and earth science program of the department.

• 1640

In dealing with the successive cutbacks, we have tried to manage the situation as well as we could, bearing in mind the guidelines that were given to us by central agencies including Treasury Board that as much as possible, we should try to protect the employees and facilitate their transfer when jobs are no longer available for them.

So there is a complex set of rules: first, that the employees who are on term employment after a certain number of years have to be granted indeterminate status, which then gives them protection when they are declared surplus. We have a long period of time in which we have to carry these employees until they find some other employment or are sort of recycled on new programs.

To make a long story short, the result is that we found ourselves in a shrinking envelope with little elbow room left and in order to cope with the cutback of $50 million that was decreed in 1986, if I am right, of which the mineral and earth science program of EMR covered about $30 million, we had to give up the capital replacement program.

Now we are finding ourselves with a lot of employees in antiquated facilities that in some instances do not meet the modern standards of health and hygiene or safety. We have a lot of backlog to catch up with.

We conducted a major study last year with a consultant at a cost of $1 million, if I remember correctly, to analyse our needs in the coming decades and the figure is quite frightening. It is not something we can undo from within the department and that has added up to the problem we are facing with the large, obviously, inventory of scientific equipment which in many instances needs to be renewed.

We sometimes have a cynical comment that the equipment we find in our laboratories you would find better in some high schools or CEGEPs of the country, so it is quite clear that this is a challenge we have to meet. It is a challenge we are taking very seriously.

[*Translation*]

et plus particulièrement les responsables du Programme des minéraux et des sciences de la terre.

Suite au budget de novembre 1984, le budget du ministère a été sérieusement réduit. Comme vous l'a je pense expliqué le ministre, M. Masse, lors de sa dernière rencontre avec vous, c'est surtout le Programme énergétique du ministère de l'Energie, des Mines et des Ressources qui a été frappé par cette réduction. Il y a eu en quelque sorte débordement car certaines de ces activités ont été assumées dans le cadre du programme des minéraux et des sciences de la terre.

Pour vous parler des compressions suscessives, nous avons tenté de gérer nos opérations du mieux que nous le pouvions, dans le cadre des directives que nous avait données les organismes centraux, y compris le Conseil du Trésor. Nous avons cherché à protéger les employés et à faciliter leur transfert lorsque nous n'avions plus d'emploi pour eux.

Les règlements sont donc complexes: premièrement, les employés temporaires doivent recevoir, après un certain nombre d'années, un statut indéterminé, ce qui les protège lorsqu'ils sont déclarés excédentaires. Nous devons conserver ces employés pendant longtemps jusqu'à ce qu'ils trouvent un autre emploi ou qu'ils soient recyclés dans le cadre de nouveaux programmes.

Pour résumer, il s'ensuit que nous nous trouvons dans une enveloppe qui se réduit et que nous avons très peu de marge de manoeuvre pour faire face aux compressions de 50 millions de dollars annoncées en 1986, si je ne me trompe pas, et le programme des minéraux et des sciences de la terre représentait 30 millions de dollars; nous avons donc dû laisser tomber le programme de remplacement de capital.

Nous nous trouvons maintenant avec beaucoup d'employés dans des installations désuètes; dans bien des cas elles ne répondent pas aux normes modernes de santé et de sécurité au travail. Nous devons rattraper beaucoup de retard également.

Nous avons fait une étude importante l'automne dernier de concert avec un expert-conseil. Si je me souviens bien, il nous a coûté un million de dollars, car nous voulions analyser nos besoins pour les décennies futures, les chiffres étaient terrifiants. Ce n'est pas quelque chose que nous pouvons démenteler au sein du ministère, par conséquent, le problème se trouve exacerbé car nous faisons face, bien sûr, à un inventaire important d'équipement scientifique qui dans bien des cas devrait être renouvelé.

On entend parfois la remarque que les écoles secondaires ou les CEGEP du pays possèdent un équipement meilleur que celui que l'on trouve dans nos laboratoires. Il est donc très évident que nous devons relever le défi. C'est un défi que nous prenons très au sérieux.

[*Texte*]

Management has been working very hard with Treasury Board in trying to develop formulas that would allow us to re-establish the leading edge that these facilities should have. We have not found a solution yet. It is quite clear that it will have to be done at the expense of some reduction in the manpower. We have come to the conclusion that we would be better served with a slightly reduced manpower, preferably through attrition, but provided with better facilities and more modern equipment in some instances.

The Chairman: Dr. Perron, did Treasury Board set the criteria or the rules that gave some parts of EMR CARP funding such as the surveying and mapping and earth sciences, whereas other parts of EMR did not receive. . .?

Dr. Perron: Well, Madam Chairman, it is part of the catch-22 rule at times. It is like a moving target. At one point in time the department was negotiating with Treasury Board for a capital acquisition and replacement program and Surveys and Mapping was in the position at that point in time to put forward a program which was accepted by Treasury Board.

Other parts of the department had to do extensive studies and by the time they came up with their conclusions, they were caught in the spending freeze and then in the cutback of $30 million, which meant we lost this opportunity. One sector of the program managed to get in and the other two sectors were left behind, so we are trying to cope with that. It is a very, very difficult situation, I can tell you that. It is felt that way by managers, as well.

• 1645

Mr. Stuart Mensforth (Assistant Deputy Minister, Finance and Administration, Department of Energy, Mines and Resources): To add to what Dr. Perron says, we started this work in 1983 with the Treasury Board because they felt that the plan to replace the equipment of our scientists had been ad hoc for too long.

As Dr. Perron said, the Surveys and Mapping Branch and the Earth Physics Branch managed to establish their inventories, develop their formulas, and win their plans. But by the time the other sides of the department got there, the well had run dry.

To give you some numbers, we feel that we have been missing money to the extent of $14 million a year for the last two to three years. If they had approved all our plans, based on the success we had with Surveys and Mapping and Earth Physics, that is the kind of additional capital money we would have been winning.

To go to the other side, which is equally disturbing—the facilities management plant—we did get an approval from the Treasury Board to survey all of the special

[*Traduction*]

Les gestionnaires ont travaillé en étroite collaboration avec le Conseil du Trésor pour mettre au point des formules qui nous permettraient de revenir en tête sur le plan de nos installations. Nous n'avons pas encore trouvé de solution. Il est bien clair que ça devrait être fait au prix d'une réduction de main-d'oeuvre. Nous en sommes venus à la conclusion que nous pourrions mieux fonctionner avec une main-d'oeuvre légèrement réduite, de préférence par voix d'attrition, tout en obtenant de meilleures installations et un équipement plus moderne dans certains cas.

La présidente: Monsieur Perron, le Conseil du Trésor a-t-il établi des critères ou des règlements pour accorder à EMR CARP un financement pour les levés, la cartographie et aussi les sciences de la terre, alors que d'autres secteurs d'EMR n'ont rien reçu. . .?

M. Perron: Madame la présidente, c'est un peu un question sans issue. C'est comme une cible mouvante. À un moment donné le ministère négocie avec le Conseil du Trésor au sujet du programme d'immobilisations pour les achats et les remplacements et les levés de la cartographie étaient en mesure à ce moment de présenter un programme qui a été accepté par le Conseil du Trésor.

D'autres secteurs du ministère devaient faire des études exhaustives et lorsqu'ils en sont venus à leur conclusion, ils ont été pris dans les réductions de dépenses, la compression de 30 millions de dollars, ce qui signifie que nous avons perdu cette occasion. Un des secteurs a pu aller de l'avant et deux autres ont été laissés pour compte, par conséquent nous essayons de nous en tirer. Il s'agit d'une situation extrêmement difficile, je vous l'assure. Les gestionnaires voient également la chose de cette façon.

M. Stuart Mensforth (sous-ministre adjoint, Finances et administration, ministère de l'Énergie, des mines et des ressources): À la suite de M. Perron, j'ajouterai que nous avons commencé ce travail en 1983 auprès du Conseil du Trésor car ces derniers étaient d'avis que le projet de remplacement de l'équipement de nos chercheurs avait été un projet spécial pendant trop longtemps.

Comme l'a dit M. Perron, la Direction des levés et de la cartographie et la Direction de la géophysique ont réussi à établir leurs inventaires, à mettre au point leurs formules et à faire passer leurs projets. Dans l'intervalle, les autres secteurs du ministère avaient pris de l'avance, et il n'y avait plus d'argent.

Je peux vous citer des chiffres, nous estimons que nous avons eu un manque à gagner de quelque 14 millions de dollars par année depuis deux ou trois ans. Si on avait approuvé tous nos projets, en se fondant sur les succès que nous avons connus avec les levées et la cartographie et la géophysique, c'est le genre de financement additionnel que nous aurions pu obtenir.

Par ailleurs, ce qui nous inquiète également—pour ce qui est de la gestion des installations—nous avions obtenu du Conseil du Trésor l'autorisation d'utiliser tous les

[*Text*]

purpose buildings that we knew Public Works would be handing over to us this last April. There were 56 of them; all buildings housing scientists, scientific laboratories, etc. We spent a million and a quarter finding out the state of those buildings.

We have put a submission to the Treasury Board, asking for the funds and the people to manage the buildings and bring them back to a state of good repair. The amount of money we are talking about is about $160 million over an eight-year period. Obviously, there is not $160 million to spare, so we have been told by Treasury Board that the money they do give us will be for occupational health and safety issues.

In the estimates before you now, there is an incremental $10 million, which has been given to the department to run the utilities of our buildings and to pay the fees of Public Works for doing this. But on top of that, we feel we need money to repair and renovate the buildings. We now have a very comprehensive study and a very good fix on the state of repair of our buildings. It is pretty sad.

Dr. Perron: If I may add, I would not like to be misinterpreted in my comments. The department has not been treated unfairly by central agencies in any way, shape, or form. Quite the contrary, we often claim that managers should be allowed to manage and, as managers, we have made our choices.

We are the ones who have decided to manage the cutbacks that we had to face, just like any other department in town, in a given way. In a way, we have painted ourselves into a corner and now we have to reassess the various options in front of us as managers. We have to make the decisions from that process. It is not a very easy situation. We are not managing growth any more.

The Chairman: You have to set your priorities.

Mr. MacLellan: Dr. Perron, we were discussing these coal projects. I think a great deal stands to be gained if these programs and these projects are successful, but we have various projects that are being worked on. We have the fluidized bed that was at Chatham. We have the coal and water that was in Charlottetown. We have the Carbogel that Devco was working on in Cape Breton. We have the proposal of the synfuels program for the Strait of Canso. We just heard that CANMET, which is an excellent facility, is doing work on the sulphur emissions.

Somewhere in there there is a real chance for Canada to have state-of-the-art technology which will not only burn high sulphur coal, but burn it cleanly, burn it economically. Possibly this can be further diverted into the burning of garbage and other waste which would be a tremendous boon to not only Canada but also to large cities in the United States and other metropolitan areas.

[*Translation*]

édifices à vocation spéciale que le ministère des Travaux publics devait nous remettre en avril dernier. Il y en avait 56, tous ces édifices logeaient des chercheurs, des laboratoires scientifiques et autres. Nous avons dépensé 1,250,000$ pour savoir dans quel état étaient ces édifices.

Nous avons présenté une demande au Conseil du Trésor pour obtenir un financement et des gens pour administrer les édifices et les remettre en état. Il s'agit donc de quelque 160 millions de dollars sur une période de huit ans. On n'avait pas, bien sûr, 160 millions de dollars à nous remettre et, par conséquent, le Conseil du Trésor nous a dit que le financement qui nous sera remis devait être consacré à la sécurité et à la santé au travail.

Le budget que vous avez devant vous comprend une somme additionnelle de 10 millions de dollars, qui a été accordée au ministère pour administrer les services de nos édifices et pour payer les Travaux publics qui s'en chargent. En plus de cela, nous sommes d'avis qu'il nous faudrait de l'argent pour réparer et rénover ces édifices. Nous avons fait une étude très complète et nous savons très bien ce qu'il faudrait comme réparations à ces édifices.

M. Perron: J'aimerais ajouter que je ne voudrais pas qu'on interprète mal mes paroles, que le ministère n'a pas été traité de façon injuste par les organismes centraux, de quelque façon que ce soit. Bien au contraire, nous répétons souvent que les gestionnaires devraient pouvoir gérer, et en tant que gestionnaires, nous avons fait nos propres choix.

C'est nous qui avons décidé d'administrer les compressions budgétaires auxquelles nous devons faire face, comme pour tout autre ministère à Ottawa. D'une certaine façon, nous nous sommes placés dans une situation et maintenant, nous devons réévaluer les diverses options qui s'offrent à nous en tant que gestionnaires. Nous devons prendre des décisions dans ce sens. Ce n'est pas une situation très facile. Il n'est pas question maintenant d'administrer une situation de croissance.

La présidente: Vous devez établir vos priorités.

M. MacLellan: Monsieur Perron, nous avons discuté de ces projets houillers. Je crois qu'on pourrait récolter de gros profits si ces programmes et ces projets réussissaient, mais nous travaillons à divers projets. Nous avons, par exemple, le gisement fluidisé à Chatham. Nous avons le charbon et l'eau à Charlottetown. Nous avons également Carbogel auquel Devco travaille au Cap Breton. Nous avons une proposition au sujet des programmes de combustible du détroit de Canso. Nous venons d'apprendre que CANMET, une excellente installation, travaille sur les émissions sulfureuses.

Il existe donc quelque part la possibilité pour le Canada d'avoir une technologie des plus modernes qui permettrait non seulement de brûler du charbon à haute teneur en soufre, mais de le brûler proprement et économiquement. On pourrait peut-être également l'utiliser pour brûler les déchets ménagers et autres déchets, ce qui serait extraordinaire non seulement pour

[*Texte*]

Where do we stand in all of this and where is the department heading? Are they pruning any of these projects? Are some projects better than others? What is the time schedule?

• 1650

Dr. Perron: Thank you very much, Mr. MacLellan. I could not but agree with your own assessment. First, it provides me with an opportunity to review the very extensive commitment that we have toward coal at Energy, Mines and Resources. As a large department, we have many mechanisms through which we have been working with the coal industry.

First, within CANMET: I am sure you are aware that we have two main coal research laboratories, one in Cape Breton and one in Devon, a suburb of Edmonton, co-located with the Alberta Research Council group also working on coal and we have a small group here in Ottawa.

Second, over the past six, seven years we have had the Coal Demonstration Program that allowed some major, major projects to be undertaken. I do hope you have seen the Chatham power station that Minister Merrithew inaugurated last August with his provincial counterparts. It is a first-class, world-class facility, a facility that is very flexible, that is second to none in the world, that is very versatile and can be used to test and will be used to test fuels and various options on a cost recovery basis as a contract facility. We will be working with our provincial colleagues to ensure that this facility is indeed operated for what it was designed in the long term.

As well, I am sure you have also seen the facility that was built by the Cape Breton Development Corporation with our financial assistance to produce Carbogel, or water-coal mixture. It is again a first-class facility that has all of what is required, I am sure. If you have visited it, you will have come to the same conclusion. It has all that is required to produce very reasonable quantities of fuel for demonstration purposes and for market tests and even for some clients. So we would hope and we will ensure ourselves that the facility is indeed used for that purpose. There is no sense now in building a major facility to produce that type of fuel unless the market is there, and that is where we have to concentrate our efforts in the next decade or the coming years.

There are many, many other options available to us on which we are working on many fronts and it seems to me that this is truly a reflection of the very strong commitment of EMR to work with the coal industry and

[*Traduction*]

le Canada, mais pour d'autres grosses villes des États-Unis et d'autres grandes régions métropolitaines.

Où en sommes-nous dans tout cela et vers quoi se dirige le ministère? Est-ce qu'on essaie de dégraisser ces projets? Est-ce que certains projets sont meilleurs que d'autres? Quel est l'échéancier?

M. Perron: Merci bien, monsieur MacLellan. Je ne peux que souscrire à vos remarques. Premièrement, vous m'offrez ainsi l'occasion de passer en revue notre engagement profond envers le charbon au sein d'Énergie, Mines et Ressources Canada. Étant un grand ministère, nous avons de nombreux mécanismes qui nous permettent de nous concerter avec l'industrie houillère.

Tout d'abord, CANMET: comme vous le savez, sans aucun doute, nous avons deux grands laboratoires de recherche sur le charbon, l'un au Cap Breton, l'autre à Devon, dans la banlieue d'Edmonton, où ils partagent des locaux avec un groupe de recherche sur le charbon du Conseil de recherche de l'Alberta, et nous avons aussi un petit groupe de chercheurs ici même, à Ottawa.

Deuxièmement, depuis six ou sept ans, nous avons mis en oeuvre nos programmes de démonstration du charbon qui a abouti à quelques réalisations des plus importantes. J'espère que vous avez visité la centrale de Chatham, que le ministre Merrithew et ses homologues provinciaux ont inaugurée en août dernier. Il s'agit d'une installation sans pareille, d'envergure mondiale, dont la souplesse d'exploitation ne le cède à aucune autre, qui est propre à de multiples usages et qui peut s'employer—et elle le sera—à la mise à l'essai, par voie forfaitaire, de divers combustibles et de diverses options pour le recouvrement des coûts. Nous collaborerons avec nos homologues provinciaux pour faire en sorte que cette installation serve aux fins à long terme pour lesquelles elle a été conçue.

En outre, je n'ai aucun doute que vous avez également visité l'installation aménagée par la Société de développement du Cap Breton, grâce à notre concours financier, afin de produire du Carbogel, un combustible charbon-eau. Encore une fois, c'est une installation de premier ordre qui a tout ce qu'il faut, je n'en doute pas. Si vous l'avez visitée, vous en serez venus à la même conclusion. Elle a tout ce qu'il faut pour produire des quantités fort raisonnables de combustibles à des fins de démonstration ou d'essai, voire même pour une certaine clientèle. Nous comptons bien que cette installation servira à cette fin; d'ailleurs, nous allons nous en assurer. Il serait absurde d'aménager un centre de production aussi important, à moins qu'il n'y ait des débouchés pour ce genre de combustible; voilà pourquoi nous devons concentrer nos efforts sur le marché d'ici la prochaine décennie ou au cours des années à venir.

Il y a une foule d'autres options qui sont à notre portée et auxquelles nous travaillons sur bien des fronts; il me semble que cela reflète effectivement l'engagement profond de notre ministère de se concerter avec

[*Text*]

with the co-producing agents of this country to improve the lot of the industry in the next decades.

Mr. MacLellan: Dr. Perron, thank you very much for that. But I am just not sure in my own mind that these projects are economical yet. I think they are still more or less in the exploratory stages and I am worried about getting them to the point, particularly with possible competition from other countries, where they are marketable units and then as a technology that will be able to be sold worldwide. I am afraid we are just going to stay at this level. We are not going to pursue it. You are going to say it is time for the private sector to take it over and the private sector may not be interested in taking it over. I fear this whole technology is just going to remain stagnant and we are not going to get that thrust that we really need. It is going to fall between stools, between CANMET or between the National Research Council, between pilot projects, whatever. And all that we have done and all the expectations that have been created are not going to be realized.

Dr. Perron: I guess the answer has to be on the one hand and on the other hand. On the one hand, we have a strong commitment and I believe we have demonstrated that over the past—that the facilities and the programs still available to us and to other departments as well are indeed good ways of ensuring that these opportunities will not be lost. Quite the contrary.

On the other hand, there is always a difficult strategic choice to make as to when you say enough is enough on a given project, and unless you get tangible commitment from the private sector or genuine interest shown by the marketplace, these initiatives have to be maintained but at the rate at which things can develop. We often joke by saying that it is like treading a wet noodle.

• 1655

Technology transfer is a difficult business. Indeed, all of these technologies have the difficulty of having to compete in a market where the commodity prices tend to be very soft, and are likely to remain soft for quite some time. There is always the possibility of inter-fuel switching. These are opportunities we have to look at and capture when they are available.

But it is not through lack of commitment or through lack of programs on our part, even though there is always the possibility of spending a great deal more money when money is available. We have critical choices to make, and we believe we are now making the right choices.

The Chairman: We had TransAlta before the committee two or three weeks ago, and they were discussing their integrated gasification combined-cycle system, which will take high-sulphur coal and remove nitrous and sulphur dioxides. They are near the

[*Translation*]

l'industrie houillère et avec les coproducteurs canadiens afin d'améliorer le sort de cette industrie au cours des prochaines décennies.

M. MacLellan: Monsieur Perron, merci bien pour tout cela. Mais je me demande toujours si ces prorammes sont encore rentables. À mon sens, nous en sommes toujours au stade de l'exploration, à peu de choses près, et je me demande si nous pourrons mettre la technologie au point, face surtout à la concurrence possible d'autres pays, si l'on veut aboutir à des installations commercialisables et à une technologie que nous pourrions écouler à l'échelle mondiale. Je crains que nous nous en tenions au premier stade, que nous ne pousserons pas les choses plus loin. Vous me direz qu'il est temps que le secteur privé prenne la relève, mais il se peut qu'il ne soit pas intéressé à prendre la relève. Je crains que cette technologie demeure dans un état stagnant, que nous ne nous donnions pas cette impulsion qui s'impose. Elle se perdra entre deux chaises, entre le CANMET ou le Conseil national de recherches, entre des projets-pilotes, que sais-je? Tout ce que nous aurons fait, tous les espoirs que nous aurons suscités, n'aboutiront à aucune réalisation.

M. Perron: La réponse à cela, j'imagine, c'est qu'il faut voir la chose sous tous les angles. D'une part, il y a notre engagement profond, que nous croyons avoir manifesté dans le passé—les installations et les programmes dont nous disposons toujours, dont tous les autres ministères disposent aussi, nous permettent de croire que nous n'allons rater aucune bonne occasion, au contraire.

D'autre part, sur le plan stratégique, le choix est toujours difficile à faire entre continuer un programme et y mettre fin; à moins d'obtenir un engagement manifeste de la part du secteur privé ou de déceler un intérêt réel sur le marché, de telles initiatives peuvent se poursuivre, mais à l'allure à laquelle les choses peuvent évoluer. Nous disons souvent, pour rire, que cela équivaut à enfiler des nouilles mouillées dans une aiguille.

Le transfert de la technologie n'est pas chose facile. En fait, toute technologie doit surmonter l'obstacle de la concurrence sur des marchés où les prix des produits tendent à fluctuer, phénomène qui est appelé à se perpétuer pour quelque temps. Il y a toujours la possibilité de faire un échange de combustible. Voilà les occasions sur lesquelles nous devons sauter, lorsqu'elles se présentent.

Mais ce n'est pas faute d'engagement ou faute de programmes de notre part, quoi que la possibilité existe toujours de trop dépenser lorsqu'on dispose de fonds. Nous avons des choix cruciaux à faire mais nous estimons avoir fait un bon choix en ce moment.

La présidente: Lorsque TransAlta a comparu devant le Comité, il y a deux ou trois semaines, on a discuté d'un régime intégré de gazification à cycle combiné, qui serait à base de charbon à haute teneur en soufre dont les bioxides d'azote et de soufre seraient enlevés. Le projet en

[*Texte*]

commercial stage, where they can sell off their technology. It was very interesting.

Mr. Gustafson: I have a couple more questions relating to uranium. You mentioned the deposits of uranium in Saskatchewan compared with Saudi Arabia's oil deposits. There are a couple of things that to me, a complete novice on the subject. . . you mentioned international companies, European and Japanese, investing. Are the companies in energy supply today in other areas, such as coal and oil, interested in this commodity? Certainly in your department competition must be real. You must have some very significant lobbying from the coal-mining industry and the oil industry. It would appear to me, as a novice on the subject, when I see those people investing in uranium, we are probably going to see some development.

Mr. Merrithew: Your point is well taken. I do not think there is the level of interest in that that there was, say, in the early 1970s, when it was emerging and some very large companies were in and eventually got out of it. We still have very large companies in—for example, Eldorado, SMDC, Denison.

Mr. Gustafson: What about Petro-Canada?

Mr. Merrithew: You are talking about your own province. It seems to me it is all tied up with SMDC there. But maybe I should have somebody else comment on it.

Dr. Perron: The major petroleum and gas companies were interested in the uranium business some time ago. In fact, outside of Saskatchewan most of the exploration for uranium was conducted by the major gas companies. They have now all withdrawn from that area, and the companies that are active are the likes of German ones such as Urangesellschaft, Uranerz; the French COGEMA; Kepco, in partnership—Kepco is Korean—Idemitsu Kosan, from Japan, which is more interested in taking a greater share in projects like that of Cigar Lake. These are the major players now.

Idemitsu Kosan is a company that is very interesting. It has an energy interest in Japan, and it is looking at that project as a way of diversifying. But as for the other companies, mainly they are intermediaries between utilities and a source of fuel.

Mr. Gustafson: What about the cost of producing energy? How does uranium compare, for instance, with other sources?

Dr. Perron: It depends on whether you are talking about the cost of fuel itself or you are talking about the whole—

Mr. Gustafson: I am talking about the cost of delivering power to this light bulb.

Dr. Perron: We are told the analysis conducted of Ontario Hydro investment in the nuclear power industry

[*Traduction*]

est presque au stade commercial, et cette technologie pourrait être vendue. C'était un exposé des plus intéressants.

M. Gustafson: J'ai quelques autres questions au sujet de l'uranium. En parlant des gisements d'uranium de la Saskatchewan, vous les avez comparés aux gisements pétroliers de l'Arabie Saoudite. Il y a certaines choses qui, pour moi, un pur profane. . . vous avez parlé de sociétés internationales, européennes et japonaises, en tant qu'investisseurs. Les sociétés qui fournissent de nos jours d'autres sources d'énergies, comme le charbon et le pétrole, sont-elles intéressées à ce produit? Les doutes que vous ressentez des effets de la concurrence au sein du ministère. Vous devez recevoir souvent des lobyistes des sociétés minières et pétrolières. Pour moi, simple profane, lorsque je vois quelqu'un investir dans l'uranium, c'est probablement parce qu'on en espère quelque chose.

M. Merrithew: Votre remarque est tout à fait valable. Je dirais qu'on y manifeste en ce moment moins d'intérêt qu'auparavant, disons au début des années 1970, lorsque l'idée a fait surface et que certaines sociétés importantes s'y sont intéressées, mais pour un certain temps seulement. Il y a encore des sociétés importantes qui s'y intéressent, par exemple, Eldorado, SMDC, Denison.

M. Gustafson: Et Petro-Canada?

M. Merrithew: Là, vous parlez de votre propre province. Je crois, dans ce cas, que tout est lié à la SMDC. Je devrais peut-être demander l'opinion de quelqu'un d'autre à ce sujet.

M. Perron: Les principales sociétés de pétrole et de gaz se sont intéressées, il y a quelque temps, à l'uranium. En fait, hors de la Saskatchewan, l'exploration de l'uranium a été le fait des grandes sociétés gazières. Elles ont toutefois cessé leurs activités dans ce domaine, et les seules qui soient encore actives sont des entreprises comme les sociétés allemandes Urangesellschaft, Uranerz; la société française COGEMA; Kepco, en association—Kepco est une société coréenne—Idemitsu Kosan, du Japon, qui s'intéresse surtout à obtenir une plus grande part de projets tels que celui de Cigar Lake. Voilà les principaux intéressés de nos jours.

Idemitsu Kosan est une société des plus intéressantes. Elle possède des intérêts énergétiques au Japon; pour elle, c'est un moyen de se diversifier. Toutefois, quant aux autres sociétés, ce sont surtout des intermédiaires entre les sociétés d'utilité publique et les sources de combustible.

M. Gustafson: Et les frais de production d'énergie? À ce propos, comment l'uranium se compare-t-il à d'autres sources d'énergie?

M. Perron: C'est selon; s'agit-il du coût du combustible lui-même ou bien de toute. . .

M. Gustafson: Je parle de ce qu'il en coûte pour allumer cette ampoule.

M. Perron: On nous dit que, selon les analyses effectuées par l'Hydro-Ontario quant à ses investissements

[*Text*]

has allowed Ontario Hydro to save a few billion dollars over the past decade. So it is a very significant saving.

• 1700

If you want to compare the cost of a kilowatt-hour and the cost of the fuel component itself, in the case of a nuclear power station the fuel component is very small. It is a few percentage points, whereas in a coal-burning or a gas-burning or an oil-burning facility it goes up to 25% or 30%, depending on the facility.

Mr. Gustafson: What about the question of risk? I would break that question down into two parts. We know what happened in Europe.

I attended an event some time ago in the House of Commons, in Room 200, put on by AECL Research Company. At that time one of the gentlemen explaining the project indicated that it was safer to stand in front of a plant fired by uranium than it was to stand in front of our lignite furnaces at Estevan, Saskatchewan, as far as human safety goes. What about pollution? What is the comparison that you people have on this subject?

Dr. Perron: Mr. Gustafson, we are entering a highly controversial subject.

Mr. Gustafson: I am well aware of that.

Dr. Perron: I do not believe we are the persons best qualified to deal with these questions, because they fall in the realm of the relative risk assessment. It is a very controversial subject. It is one that has to be approached with the right information and the right perspective. It is not something we can deal with in a few words, and I would hate to make the wrong remarks on that subject.

I believe it is a subject that would be better addressed when you have representatives of the Atomic Energy Control Board meeting with this committee, or even my colleagues of the Energy Program, who could then discuss the relative merits.

Furthermore, I believe there was a standing committee that looked at the business of the future. Is it not your committee, Mrs. Sparrow?

The Chairman: Yes, we are, Dr. Perron.

Dr. Perron: So I believe that would be better addressed in that forum, if you do not mind.

Mr. Gustafson: Could you go as far as to do a comparison of an existing plant? I am talking about—

[*Translation*]

dans les centrales nucléaires, cette dernière aurait réalisé depuis une décennie des économies de quelques milliards de dollars. Il s'agirait donc d'économies très importantes.

Si vous voulez comparer le coût d'un kilowatt-heure et le coût de l'élément combustible lui-même, dans le cas d'une centrale nucléaire, l'élément combustible compte vraiment pour une très faible part. Il ne représente que quelques points de pourcentage, tandis que dans une centrale où l'on brûle du charbon, du gaz ou du pétrole, la part correspondant au combustible passe à 25 ou 30 p. 100, selon le cas.

M. Gustafson: Et qu'en est-il de la question du risque? D'ailleurs, je diviserais la question en deux. Nous savons ce qui s'est passé en Europe.

J'ai participé, il y a quelque temps, à un événement tenu par la Société de recherche de l'énergie atomique du Canada, dans la pièce 200 de l'Immeuble de l'Ouest. À cette occasion, l'une des personnes qui fournissaient des explications sur le projet disait qu'il y avait moins de risques pour la santé humaine à se tenir debout devant une usine alimentée par l'uranium que devant une de nos chaudières à lignite à Estevan, en Saskatchewan. Qu'en est-il de la pollution? Quelle comparaison pourriez-vous nous faire à ce propos?

M. Perron: Monsieur Gustafson, il s'agit là d'une question très controversée.

M. Gustafson: Je le sais bien.

M. Perron: Je ne pense pas que nous soyons les personnes les mieux en mesure de répondre à ce genre de questions, car celles-ci relèveraient plutôt du domaine de l'évaluation relative des risques. C'est une question fort controversée qui doit être abordée avec les bons renseignements et la bonne perspective. Ce n'est pas une chose qu'on peut régler en quelques mots, et je n'aimerais pas me tromper dans ce que je dirais à ce sujet.

Je pense qu'il serait préférable que vous abordiez cette question lorsque vous entendrez des représentants de la Commission de contrôle de l'énergie atomique, ou même mes collaborateurs responsables du programme énergétique, qui pourraient vous exposer les mérites relatifs des différentes techniques.

Je pense, par ailleurs, qu'un comité permanent devait s'occuper des perspectives d'avenir. Est-ce ce comité-ci, madame Sparrow?

La présidente: Oui, monsieur Perron.

M. Perron: Si cela ne vous ennuie pas de me l'entendre dire, je pense qu'il serait préférable que vous abordiez cette question dans le cadre de cette tribune.

M. Gustafson: Pourriez-vous au moins nous donner une comparaison à partir d'une centrale existante? Je veux parler de. . .

[*Texte*]

The Chairman: I hate to cut you off, Mr. Gustafson. One quick question, Mr. Parry, and then the minister has a conference.

Mr. Parry: Madam Chair, I would of course claim the right for the same length of questioning, but as it happens I only have one quick question, which is to the minister.

Do you think that really in the past few years we have made any significant progress? I am not talking in technical terms here; I am talking in terms of economics, in terms of values. Have we made any significant progress in terms of increasing the processing of mineral products within Canada?

Mr. Merrithew: Because that is essentially on the processing side of the field and therefore more DRIE oriented, I can tell you that we have made significant progress on the basic mining side in terms of productivity and in terms of exploration, which is up significantly.

Mr. Parry: I know that.

Mr. Merrithew: But on the processing side maybe I have to get somebody to give a more technological aspect to it.

Dr. Perron: I believe that globally we have made significant progress in this country by capturing unique opportunities in the past decade. We have extended our aluminum smelting capacity in this country; there were some major projects in the province of Quebec on that front. We have also built a significant capacity in the field of ferro alloys.

As was discussed this morning at the Mineral Outlook Conference, there is no doubt that the free trade agreement will open a few more opportunities, because, even though the tariffs on mineral and metal commodities were relatively small, in relative effect on the further processing value they were very significant. It was claimed, as it was claimed in our own assessment of the impact of the free trade agreement, that this would open doors that were until now extremely difficult to open.

If you have not received a copy of our assessment of the likely impacts of the free trade agreement on the minerals and metals sector then we will be pleased to provide you with a copy.

• 1705

Mr. MacLellan: I am still not satisfied. My general concern, Madam Chairman, is that in the research and development there are going to be so many balls up in the air that things are not going to come together. It is not that I am opposed to the space program, but I am concerned about EMR reserving $2 million of its budget for the space program, and particularly CANMET reserving $800,000 or something of its budget for the space program.

[*Traduction*]

La présidente: Excusez-moi, monsieur Gustafson, mais je dois vous interrompre. Une dernière petite question, monsieur Parry, car le ministre a une conférence.

M. Parry: Madame la présidente, je revendiquerais, bien sûr, le même temps de parole, mais il se trouve que je n'ai qu'une toute petite question, qui s'adresse au ministre.

Pensez-vous que nous ayons véritablement fait d'importants progrès au cours des dernières années? Je ne parle pas ici de l'aspect technique, mais plutôt de l'aspect éconmique et des valeurs. Avons-nous sensiblement augmenté le traitement des produits minéraux au Canada?

M. Merrithew: Vous parlez là de l'aspect traitement, et cela relève plutôt du ministère de l'Expansion industrielle régionale. Je puis cependant vous dire que des progrès importants ont été réalisés du côté de la productivité et de l'exploration, où les activités ont augmenté sensiblement.

M. Parry: Je le sais.

M. Merrithew: Quant au traitement proprement dit, quelqu'un d'autre pourrait peut-être vous entretenir un peu mieux au sujet de l'aspect technologique.

M. Perron: Je pense que, dans l'ensemble, nous avons fait d'importants progrès au Canada en saisissant au cours de la dernière décennie un certain nombre de possibilités tout à fait uniques. Nous avons notamment augmenté notre capacité de production d'aluminium. Un certain nombre de projets importants ont été lancés dans ce domaine au Québec. Nous avons également constitué une capacité importante dans le domaine des ferro-alliages.

Comme cela a été dit ce matin dans le cadre de la Conférence sur les perspectives minérales, il n'y a aucun doute que l'accord de libre-échange créera de nouvelles possibilités car, même si les tarifs douaniers applicables aux minerais et aux métaux étaient assez bas, ils étaient beaucoup plus importants sur les produits ayant subi des traitements plus poussés. Il a été dit—et c'est ce que nous avons nous-mêmes dit dans notre évaluation de l'incidence de l'entente de libre-échange—que cela ouvrira des portes qu'il nous a été jusqu'ici très difficile d'ouvrir.

Si vous n'avez pas reçu un exemplaire de notre évaluation de l'incidence de l'entente de libre-échange sur le secteur des minerais et des métaux, nous nous ferons un plaisir de vous en faire parvenir un.

M. MacLellan: Je ne suis toujours pas satisfait. Madame la présidente, ce que je crains, c'est qu'en matière de recherche et de développement, il y ait tant de choses en route que cela ne débouche sur rien. Non pas que je m'oppose au programme spatial; tout simplement, je m'inquiète de ce que le ministère de l'Énergie, des mines et des ressources réserve deux millions de dollars de son budget pour ce programme, tandis que CANMET lui réserve quelque 800,000$.

[*Text*]

The Chairman: Perhaps you could get in touch with Minister Merrithew, or Dr. Perron.

I would very much like to continue this meeting, and I would ask the committee members to stay for a few minutes.

Mr. Minister, thank you very much for coming and giving us a very informative presentation, and answering our questions. We truly appreciate it and look forward to seeing you at the Mineral Outlook Conference later this evening.

Committee members, we do have a quorum here to deal with the estimates. We have reviewed all our estimates. I would ask that we vote on them now so they could be reported to the House.

We have votes 1, the Administation of EMR; votes 5, 10 and 15, the Energy Program; Vote L20, a statutory one, but we must carry that; Votes 25, 30 and 35, Mining; Vote 40, AECB; Vote 45, AECL; Vote 50, NEB, and Vote 55, Petro-Canada International Assistance Corporation.

ENERGY, MINES AND RESOURCES

Administration Program

Vote 1—Program expenditures $41,787,000

Energy Program

Vote 5—Operating expenditures $92,094,000

Vote 10—Grants and contributions $25,659,000

Vote 15—Canadian Exploration and Development Incentive Program $259,000,000

Vote L20—Loans to finance regional electrical interconnections $9,053,000

Minerals and Earth Sciences Program

Vote 25—Operating expenditures $260,504,000

Vote 30—Capital expenditures $38,501,000

Vote 35—Grants and contributions $45,418,000

Atomic Energy Control Board

Vote 40—Program expenditures $22,243,000

Atomic Energy of Canada Limited

Vote 45—Payments to Atomic Energy of Canada Limited for operating and capital expenditures......... .... $141,997,000

National Energy Board

Vote 50—Program expenditures $21,746,000

Petro-Canada International Assistance Corporation

Vote 55—Payments to Petro-Canada International Assistance Corporations $60,500,000

[*Translation*]

La présidente: Vous pourriez peut-être communiquer plus tard avec M. Merrithew ou avec M. Perron.

J'aimerais beaucoup poursuivre cette réunion, et je demanderais aux membres du Comité de rester encore quelques minutes.

Monsieur le ministre, merci beaucoup d'être venu nous rencontrer, et merci pour votre exposé informatif et pour vos réponses à nos questions. Nous vous en sommes très reconnaissants et nous attendons avec impatience de vous revoir plus tard, ce soir, à la Conférence sur les perspectives minérales.

Mesdames et messieurs, nous avons le quorum nécessaire pour traiter des prévisions budgétaires. Nous les avons toutes examinées. Je demanderais qu'on les mette tout de suite aux voix afin que nous puissions présenter notre rapport à la Chambre.

Nous avons les crédits 1, Administration du ministère; les crédits 5, 10 et 15, pour le programme de l'énergie; le crédit L20, un crédit statutaire qui doit être maintenu; les crédits 25, 30 et 35, mines; le crédit 40, Commission de contrôle de l'énergie atomique; le crédit 45, Énergie atomique du Canada, Limitée; le crédit 50, Office national de l'énergie; et le crédit 55, la Corporation Petro-Canada pour l'assistance internationale.

ÉNERGIE, MINES ET RESSOURCES

Programme d'administration

Crédit 1—Dépenses du Programme $41,787,000

Programme de l'énergie

Crédit 5—Dépenses de fonctionnement $92,094,000

Crédit 10—Subventions et contributions ... $25,659,000

Crédit 15—Programme canadien d'encouragement à l'exploration et à la mise en valeur $259,000,000

Crédit L20—Prêts pour financer l'interconnexion régionale de réseaux de transport de l'électricité....... .... $9,053,000

Programme des minéraux et des sciences de la Terre

Crédit 25—Dépenses de fonctionnement . $260,504,000

Crédit 30—Dépenses en capital $38,501,000

Crédit 35—Subventions et contributions ... $45,418,000

Commission de contrôle de l'énergie atomique

Crédit 40—Dépenses du programme $22,243,000

Énergie atomique du Canada, Limitée

Crédit 45—Paiements à Énergie atomique du Canada, Limitée pour les dépenses de fonctionnement et les dépenses en capital $141,997,000

Office national de l'énergie

Crédit 50—Dépenses du Programme $21,746,000

La Corporation Petro-Canada pour l'assistance internationale

Crédit 55—Paiements à la Corporation Petro-Canada pour l'assistance internationale $60,500,000

[*Texte*]

Votes 1, 5, 10, 15, L20, 25, 30, 35, 40, 45, 50 and 55 agreed to.

The Chairman: Shall I report the estimates to the House?

Some hon. members: Agreed.

The Chairman: Thank you very much.

Now, tomorrow morning, Mr. MacLellan, I believe we are busing it are we?

Mr. MacLellan: I guess we have to.

The Chairman: At 8 a.m. we are going to Kanata.

Thank you very much, Mr. Parry, Mr. Gustafson.

The meeting is adjourned.

[*Traduction*]

Les crédits 1, 5, 10, 15, L20, 25, 30, 35, 40. 45, 50 et 55 sont adoptés.

La présidente: Le Comité doit-il déposer les prévisions budgétaires auprès de la Chambre?

Des voix: D'accord.

La présidente: Merci beaucoup.

Monsieur MacLellan, si j'ai bien compris, nous devons prendre l'autobus demain matin, n'est-ce pas?

M. MacLellan: Je pense que nous n'avons pas le choix.

La présidente: Nous partons pour Kanata à 8 heures.

Merci beaucoup, messieurs Parry et Gustafson.

La séance est levée.

Canada Post Postage paid
Postes Canada Port payé
Book rate Tarif des livres
K1A 0S9
OTTAWA

If undelivered, return COVER ONLY to
Canadian Government Publishing Centre,
Supply and Services Canada,
Ottawa, Canada, K1A 0S9

En cas de non-livraison,
retourner cette COUVERTURE SEULEMENT à
Centre d'édition du gouvernement du Canada,
Approvisionnements et Services Canada,
Ottawa, Canada, K1A 0S9

WITNESSES

Senior Officials from the Ministry of Forestry and Mines:

Pierre O. Perron, Associate Deputy Minister;

Stuart Mensforth, Assistant Deputy Minister, Finance and Administration;

Marc Denis Everell, Assistant Deputy Minister, Mineral and Energy Technology Sector;

D.C. Findlay, Director General, Continental Geoscience and Mineral Resources;

Nancy Mitchell, Director, Coal Division, Mineral Policy Sector.

TÉMOINS

Hauts fonctionnaires du Cabinet du ministre d'État (Forêts et Mines):

Pierre O. Perron, sous-ministre associé;

Stuart Mensforth, sous-ministre adjoint, Finances et administration;

Marc Denis Everell, sous-ministre adjoint, Secteur de la technologie et de l'énergie;

D.C. Findlay, directeur général, Direction de la géologie du continent et des ressources minérales;

Nancy Mitchell, directeur, Division du charbon, Secteur de la politique minérale.

Available from the Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Canada K1A 0S9

En vente: Centre d'édition du gouvernement du Canada, Approvisionnements et Services Canada, Ottawa, Canada K1A 0S9

HOUSE OF COMMONS

CHAMBRE DES COMMUNES

Issue No. 47

Fascicule nº 47

Wednesday, June 1, 1988
Thursday, June 2, 1988
Wednesday, June 8, 1988
Monday, June 13, 1988
Thursday, June 16, 1988

Le mercredi 1er juin 1988
Le jeudi 2 juin 1988
Le mercredi 8 juin 1988
Le lundi 13 juin 1988
Le jeudi 16 juin 1988

Chairman: Barbara Sparrow

Présidente: Barbara Sparrow

Minutes of Proceedings and Evidence of the Standing Committee on

Energy, Mines and Resources

Procès-verbaux et témoignages du Comité permanent de

L'énergie, des mines et des ressources

RESPECTING:

Consideration of a draft report

In accordance with its mandate under Standing Order 96(2), an examination of the economics of nuclear power in Canada

CONCERNANT:

Considération de l'ébauche d'un rapport

Conformément au mandat que lui confie l'article 96(2) du Règlement, examen de l'économique de la puissance nucléaire au Canada

WITNESS:

(See back cover)

TÉMOIN:

(Voir à l'endos)

Second Session of the Thirty-third Parliament, 1986-87-88

Deuxième session de la trente-troisième législature, 1986-1987-1988

23777—1

STANDING COMMITTEE ON ENERGY, MINES AND RESOURCES

Chairman: Barbara Sparrow

Vice-Chairman: Aurèle Gervais

Members

Paul Gagnon
Len Gustafson
Russell MacLellan
Lorne Nystrom
Bob Porter—(7)

(Quorum 4)

Eugene Morawski
Clerk of the Committee

COMITÉ PERMANENT DE L'ÉNERGIE, DES MINES ET DES RESSOURCES

Présidente: Barbara Sparrow

Vice-président: Aurèle Gervais

Membres

Paul Gagnon
Len Gustafson
Russell MacLellan
Lorne Nystrom
Bob Porter—(7)

(Quorum 4)

Le greffier du Comité
Eugene Morawski

Published under authority of the Speaker of the House of Commons by the Queen's Printer for Canada

Available from the Canadian Government Publishing Center, Supply and Services Canada, Ottawa, Canada K1A 0S9

Publié en conformité de l'autorité du Président de la Chambre des communes par l'Imprimeur de la Reine pour le Canada

En vente: Centre d'édition du gouvernement du Canada, Approvisionnements et Services Canada, Ottawa, Canada K1A 0S9

MINUTES OF PROCEEDINGS

WEDNESDAY, JUNE 1, 1988
(71)

[*Text*]

The Standing Committee on Energy, Mines and Resources met *in camera* at 3:36 o'clock p.m., in Room 253-D, this day, the Chairman, Barbara Sparrow, presiding.

Members of the Committee present: Paul Gagnon, Lorne Nystrom, Bob Porter and Barbara Sparrow.

Acting Member present: Gérald Comeau for Aurèle Gervais.

In attendance: Dean Clay, Consultant.

In accordance with its mandate under Standing Order 96(2) the Committee resumed consideration of the economics of nuclear power in Canada. (*See Minutes of Proceedings and Evidence dated Thursday, October 15, 1987, Issue No. 29.*)

The Committee proceeded to the consideration of a draft report.

At 4:50 o'clock p.m., the Committee adjourned to the call of the Chair.

THURSDAY, JUNE 2, 1988
(72)

The Standing Committee on Energy, Mines and Resources met *in camera* at 9:13 o'clock a.m., in Room 306 West Block, this day, the Chairman, Barbara Sparrow, presiding.

Members of the Committee present: Paul Gagnon, Bob Porter and Barbara Sparrow.

In attendance: Dean Clay, Consultant; Lawrence Harris, Researcher.

In accordance with its mandate under Standing Order 96(2) the Committee resumed consideration of the economics of nuclear power in Canada. (*See Minutes of Proceedings and Evidence dated Thursday, October 15, 1987, Issue No. 29.*)

The Committee resumed consideration of a draft report.

At 10:46 o'clock a.m., the Committee adjourned to the call of the Chair.

WEDNESDAY, JUNE 8, 1988
(73)

The Standing Committee on Energy, Mines and Resources met *in camera* at 12:30 o'clock p.m., in Room 208 West Block, this day, the Chairman, Barbara Sparrow, presiding.

Members of the Committee present: Paul Gagnon, Len Gustafson, Lorne Nystrom and Barbara Sparrow.

Acting Member present: Len Hopkins for Russell MacLellan.

PROCÈS-VERBAUX

LE MERCREDI 1er JUIN 1988
(71)

[*Traduction*]

Le Comité permanent de l'énergie, des mines et des ressources se réunit à huis clos, aujourd'hui à 15 h 36, dans la pièce 253-D, sous la présidence de Barbara Sparrow, (*présidente*).

Membres du Comité présents: Paul Gagnon, Lorne Nystrom, Bob Porter et Barbara Sparrow.

Membre suppléant présent: Gérald Comeau remplace Aurèle Gervais.

Aussi présent: Dean Clay, conseiller.

Conformément au mandat que lui confie le paragraphe 96(2) du Règlement, le Comité reprend l'étude de l'économique de la puissance nucléaire au Canada. (*Voir Procès-verbaux et témoignages du jeudi 15 octobre 1987, fascicule no 29.*)

Le Comité entreprend d'étudier un projet de rapport.

À 16 h 50, le Comité s'ajourne jusqu'à nouvelle convocation de la présidente.

LE JEUDI 2 JUIN 1988
(72)

Le Comité permanent de l'énergie, des mines et des ressources se réunit à huis clos, aujourd'hui à 9 h 13, dans la pièce 306 de l'édifice de l'Ouest, sous la présidence de Barbara Sparrow, (*présidente*).

Membres du Comité présents: Paul Gagnon, Bob Porter et Barbara Sparrow.

Aussi présents: Dean Clay, conseiller; Lawrence Harris, chargé de recherche.

Conformément au mandat que lui confie le paragraphe 96(2) du Règlement, le Comité reprend l'étude de l'économique de la puissance nucléaire au Canada. (*Voir Procès-verbaux et témoignages du jeudi 15 octobre 1987, fascicule n^{o} 29.*)

Le Comité reprend l'étude d'un projet de rapport.

À 10 h 46, le Comité s'ajourne jusqu'à nouvelle convocation de la présidente.

LE MERCREDI 8 JUIN 1988
(73)

Le Comité permanent de l'énergie, des mines et des ressources se réunit à huis clos, aujourd'hui à 12 h 30, dans la pièce 208 de l'édifice de l'Ouest, sous la présidence de Barbara Sparrow, (*présidente*).

Membres du Comité présents: Paul Gagnon, Len Gustafson, Lorne Nystrom et Barbara Sparrow.

Membre suppléant présent: Len Hopkins remplace Russell MacLellan.

In attendance: Dean Clay, Consultant; Lawrence Harris, Researcher.

In accordance with its mandate under Standing Order 96(2) the Committee resumed consideration of the economics of nuclear power in Canada. (*See Minutes of Proceedings and Evidence dated Thursday, October 15, 1987, Issue No. 29.*)

The Committee resumed consideration of a draft report.

At 2:05 o'clock p.m., the Committee adjourned to the call of the Chair.

MONDAY, JUNE 13, 1988
(74)

The Standing Committee on Energy, Mines and Resources met *in camera* at 6:42 o'clock p.m., in Room 307 West Block, this day, the Chairman, Barbara Sparrow, presiding.

Members of the Committee present: Paul Gagnon, Lorne Nystrom and Barbara Sparrow.

Acting Member present: Len Hopkins for Russell MacLellan.

In attendance: Dean Clay, Consultant; Lawrence Harris, Researcher.

In accordance with its mandate under Standing Order 96(2) the Committee resumed consideration of the economics of nuclear power in Canada. (*See Minutes of Proceedings and Evidence dated Thursday, October 15, 1987, Issue No. 29.*)

The Committee resumed consideration of a draft report.

At 8:35 o'clock p.m., the Committee adjourned to the call of the Chair.

THURSDAY, JUNE 16, 1988
(75)

The Standing Committee on Energy, Mines and Resources met at 12:20 o'clock p.m., in Room 307 West Block, this day, the Chairman, Barbara Sparrow, presiding.

Members of the Committee present: Paul Gagnon, Russell MacLellan, Bob Porter and Barbara Sparrow.

In attendance: Dean Clay, Consultant; Lawrence Harris, Researcher.

Witness: *From Ontario Nuclear Safety Review*: Dr. F. Kenneth Hare, Commissioner.

In accordance with its mandate under Standing Order 96(2) the Committee resumed consideration of the economics of nuclear power in Canada. (*See Minutes of Proceedings and Evidence dated Thursday, October 15, 1987, Issue No. 29.*)

The witness made an opening statement and answered questions.

Aussi présents: Dean Clay, conseiller; Lawrence Haris, chargé de recherche.

Conformément au mandat que lui confie le paragraphe 96(2) du Règlement, le Comité reprend l'étude de l'économique de la puissance nucléaire au Canada. (*Voir Procès-verbaux et témoignages du jeudi 15 octobre 1987, fascicule nº 29.*)

Le Comité reprend l'étude d'un projet de rapport.

À 14 h 05, le Comité s'ajourne jusqu'à nouvelle convocation de la présidente.

LE LUNDI 13 JUIN 1988
(74)

Le Comité permanent de l'énergie, des mines et des ressources se réunit à huis clos, aujourd'hui à 18 h 42, dans la pièce 307 de l'édifice de l'Ouest, sous la présidence de Barbara Sparrow, (*présidente*).

Membres du Comité présents: Paul Gagnon, Lorne Nystrom et Barbara Sparrow.

Membre suppléant présent: Len Hopkins remplace Russell MacLellan.

Aussi présents: Dean Clay, conseiller; Lawrence Harris, chargé de recherche.

Conformément au mandat que lui confie le paragraphe 96(2) du Règlement, le Comité reprend l'étude de l'économique de la puissance nucléaire au Canada. (*Voir Procès-verbaux et témoignages du jeudi 15 octobre 1987, fascicule nº 29.*)

Le Comité reprend l'étude d'un projet de rapport.

À 20 h 35, le Comité s'ajourne jusqu'à nouvelle convocation de la présidente.

LE JEUDI 16 JUIN 1988
(75)

Le Comité permanent de l'énergie, des mines et des ressources se réunit aujourd'hui à 12 h 20, dans la pièce 307 de l'édifice de l'Ouest, sous la présidence de Barbara Sparrow, (*présidente*).

Membres du Comité présents: Paul Gagnon, Russell MacLellan, Bob Porter et Barbara Sparrow.

Aussi présents: Dean Clay, conseiller; Lawrence Harris, chargé de recherche.

Témoin: *De l'Ontario Nuclear Safety Review*: F. Kenneth Hare, président.

Conformément au mandat que lui confie le paragraphe 96(2) du Règlement, le Comité reprend l'étude de l'économique de la puissance nucléaire au Canada. (*Voir Procès-verbaux et témoignages du jeudi 15 octobre 1987, fascicule nº 29.*)

Le témoin fait une déclaration préliminaire et répond aux questions.

At 2:20 o'clock p.m., the Committee adjourned to the call of the Chair.

Eugene Morawski
Clerk of the Committee

À 14 h 20, le Comité s'ajourne jusqu'à nouvelle convocation de la présidente.

Le greffier du Comité
Eugene Morawski

EVIDENCE

[*Recorded by Electronic Apparatus*]

[*Texte*]

Thursday, June 16, 1988

• 1215

The Chairman: Order, please.

We have a quorum to hear witnesses.

The order of the day, in accordance with our mandate under Standing Order 96.(2), is an examination of the economics of nuclear power in Canada.

It is indeed a pleasure for us to welcome Dr. Kenneth Hare here today. He has just recently come forward with the report *The Safety of Ontario's Nuclear Power Reactors*, which he did for the provincial government of Ontario.

Dr. Hare, we have had the scientific and technical review part of your report for a few days and most of us have read it. We want to congratulate you. It is well done and very concise and certainly fits right into this committee's study, the study of nuclear power in Canada, which we embarked upon probably last November. Is that right, Dean?

Mr. Dean Clay (Consultant to the Committee): Yes.

The Chairman: So your appearing before the committee is extremely timely, and we truly appreciate your taking time to come here and spend an hour or an hour and a half with us.

As I mentioned earlier to a couple of my colleagues, Dr. Hare was just appointed Chancellor at Trent University, just outside of Peterborough. Another congratulation to him for that.

Usually we start with some opening remarks from our witnesses and then pose questions. Do you have some opening remarks, sir, that you could give to us?

Dr. F. Kenneth Hare (Commissioner, Ontario Nuclear Safety Review): Madam Chairman, first of all thank you for those kind remarks. The nicest thing about being a chancellor of a university is that you finally get to be paid what you are worth; namely, nothing. It is a thoroughly unpaid job.

The Chairman: That is true.

Dr. Hare: I may say that my salary as chairman of the Ontario Nuclear Safety Review stopped on April 1 at my own request too, so I am a pensioner and delighted to be in that role.

I do not want to make an elaborate statement.

TÉMOIGNAGES

[*Enregistrement électronique*]

[*Traduction*]

Le jeudi 16 juin 1988

La présidente: Je déclare la séance ouverte.

Nous avons le quorum pour entendre des témoins.

Conformément au mandat qui nous est confié aux termes de l'article 96.(2) du Règlement, nous procédons aujourd'hui à l'examen de l'économique de la puissance nucléaire au Canada.

Nous sommes très heureux d'accueillir aujourd'hui M. Kenneth Hare dont le rapport intitulé *The Safety of Ontario's Nuclear Power Reactors* qu'il a préparé pour le gouvernement de l'Ontario vient tout juste d'être publié.

Monsieur Hare, nous avons reçu la partie de votre rapport qui porte sur l'examen scientifique et technique il y a quelques jours, et la plupart d'entre nous en ont pris connaissance. Nous tenons à vous en féliciter. Cet examen est bien fait et très concis et il s'intègre certainement à l'étude qu'a entreprise notre Comité en novembre dernier, sur l'énergie nucléaire au Canada, n'est-ce pas, Dean?

M. Dean Clay (consultant pour le Comité): Oui.

La présidente: Votre comparution devant notre Comité est donc extrêmement à propos, et nous vous remercions d'avoir bien voulu nous consacrer une heure et demie de votre temps.

Comme je l'ai dit plus tôt à quelques-uns de mes collègues, M. Hare vient tout juste d'être nommé chancelier à l'Université de Trent, tout près de Peterborough. Encore une fois, nos félicitations.

Habituellement, nos témoins nous présentent leurs remarques liminaires, et nous les interrogeons par la suite. Avez-vous des remarques liminaires à nous présenter, monsieur?

M. F. Kenneth Hare (commissaire, Commission d'étude sur la sécurité des centrales nucléaires en Ontario): Madame la présidente, c'est très aimable de votre part de dire toutes ces bonnes choses à mon sujet. Ce qui est vraiment bien, lorsqu'on est chancelier d'une université, c'est qu'on reçoit enfin le salaire qu'on mérite, c'est-à-dire rien du tout. Il s'agit d'un travail tout à fait bénévole.

La présidente: C'est vrai.

M. Hare: Permettez-moi d'ajouter qu'à ma propre demande, j'ai cessé de recevoir mon salaire à titre de président de la Commission d'étude sur la sécurité des centrales nucléaires en Ontario le 1er avril. Je suis donc pensionné et ravi de l'être.

Je n'ai pas l'intention de faire un exposé détaillé.

[*Texte*]

This was an extraordinarily difficult, in some ways very unpleasant, job, which I did in 12 months really. Fifteen months elapsed because for the first three months I could not find anywhere to work. The Ontario government could not find an office in Ontario, and we could not work without proper quarters. So it is really 12 months' work.

The report is the thing you see here; volumetrically and in mass terms, it is a great big volume of work. I wrote the technical volume, which I think you have seen, and the rest is largely the work of consultants or intervener groups, but all of it has been edited into a fairly consistent whole by my staff.

We were asked if the reactors of Ontario were safe, on three grounds. Firstly, was the hardware well designed; did it contain adequate protective measures against possible accident? Secondly, was the operating system sound; did it contain the kinds of problems that led to operator failures at Chernobyl and Three Mile Island, for example? Thirdly, were the emergency measures sound? Had the utility and the province done their job and set up emergency measures?

• 1220

I think you have already read the answers to these questions, but let me just comment on them. I do not at any point say these reactors are safe. I think that is a meaningless statement. To use an analogy, my Buick does no harm if I leave it in the garage. If I take it out on the road, it may do harm on one of three grounds: if it was badly designed and General Motors did a lousy job; secondly, if I am a bad driver and I am careless, negligent; thirdly, if the law governing the use of the road is not adequate.

We tried to answer all of these. We were not asked to go quite as far as the last one, but in our opinion we had to. We did say they were being safely operated, and our evidence is in there. I and my colleagues believe it is important to base statements about the safety of operation of reactors on the actual performance and on the health of the people who are exposed to the radiation, and we are getting past that stage where you have to compare that health with abstract things like dose limits.

We now have a long period of exposure in the work force to radiation, and we can make some assessment of the safety of the operation by looking at the health and the mortality experience of the exposed work force. This we did in great detail, and that is in there. I did that myself. That was my own special input to it.

[*Traduction*]

La préparation de ce rapport que j'ai fait en réalité en 12 mois a été extrêmement difficile et d'une certaine façon très désagréable. Quinze mois se sont écoulés parce que les trois premiers mois je ne pouvais trouver d'endroit où travailler. Le gouvernement de l'Ontario ne pouvait pas me trouver de bureau en Ontario, et nous ne pouvions pas travailler sans avoir de bureaux adéquats. Cela représente donc en réalité un travail de 12 mois.

Comme vous pouvez le voir, il s'agit d'un rapport extrêmement volumineux. J'ai rédigé le volume technique, que vous avez vu je crois, et le reste est en grande partie le résultat du travail d'experts-conseils ou de groupes d'intervenants, mais mon personnel s'est occupé d'en faire l'édition afin d'en assurer l'uniformité.

On nous a demandé si les réacteurs de l'Ontario étaient sans danger, sous trois rapports. Premièrement, le matériel est-il bien conçu; a-t-on prévu des mesures de protection adéquates en cas d'accident? Deuxièmement, le système d'exploitation est-il en bon état; pose-t-il le genre de problèmes qui ont mené aux accidents de Chernobyl et de Three Mile Island, par exemple? Troisièmement, les mesures d'urgence sont-elles valables? Le service public et la province ont-ils fait leur travail et mis en place des mesures d'urgence?

Je pense que vous avez déjà lu les réponses à ces questions, mais permettez-moi de vous faire part de certains commentaires à ce sujet. Je ne dis nulle part que ces réacteurs sont sans danger. A mon avis, une telle affirmation serait dénuée de sens. Par exemple, ma Buick est sans danger si je la laisse dans le garage. Si je la mets sur la route, elle pourrait présenter un danger pour l'une de ces trois raisons: si elle était mal conçue et que General Motors avait mal fait son travail; si j'étais mauvais conducteur et si j'étais négligent; et si les lois qui régissent l'utilisation des routes n'étaient pas adéquates.

Nous avons donc essayé de répondre à ces trois questions. On ne nous a pas demandé d'aller aussi loin que la dernière, mais à notre avis, nous devions le faire. Nous avons effectivement dit que les centrales sont exploitées de façon sécuritaire, et nous en donnons la preuve ici dans ce document. Moi-même et mes collègues estimons qu'il est important de fonder nos déclarations au sujet de la sécurité de l'exploitation des centrales sur le rendement réel et sur la santé des gens qui sont exposés aux radiations, et nous sommes en train de dépasser le stade où il faut comparer la santé à des choses aussi abstraites que des doses maximales.

La main-d'oeuvre est maintenant exposée aux radiations depuis longtemps, de sorte que nous pouvons évaluer la sécurité du fonctionnement des réacteurs en examinant l'état de santé et la mortalité de la main-d'oeuvre exposée aux radiations. C'est ce que nous avons fait, dans les détails, et on le trouve dans ce document. Je l'ai fait moi-même. C'était ma propre contribution spéciale à cette étude.

[Text]

The operating system, frankly, left us a little bit worried. As we say, we think Ontario Hydro ought to take another look at it. It is not that there is anything much wrong with it. On the contrary, if you compare it with what goes on in other countries and in other utilities, and we did in depth, it is a good system. But we thought it contained within it the seeds of its own decay, and we recommend that they take a look at this. They are in fact doing so.

I have to say that Ontario Hydro, at close quarters and under tight expert inspection, comes out very well indeed. There is no doubt that they are a technically and professionally competent organization. Whether all the economic and capital decisions taken by the hydro in the past were wise is another matter, but certainly the technical performance of the utility now in the areas we investigated earns, and I think deserves, international respect.

When we came to the law governing, we were in federal territory and we decided we would go right ahead and trespass. Nobody had asked us to look at the Atomic Energy Control Board. We did, and we were urged by many intervenor groups to say that this country ought to replace the good, grey Atomic Energy Control Board by something more closely resembling the American model, which is one of prescription and legal confrontation between the parties. We came to the conclusion that this was not necessary.

But the criticisms of the Atomic Energy Control Board, that they are too narrow in their interpretation of their mandate. . . Yes, we agreed with that, and say so, and we have made recommendations which I very much hope you will question me about—what we thought ought to happen to the board. After all, this is a territory of federal jurisdiction; nuclear safety is federal jurisdiction. Even though my mandate came from the provincial government, I felt I had to poke my nose into the federal side of things.

Finally, on emergency measures, we came to the conclusion that the Ontario government had done virtually nothing about this. This could not be tolerated, and we said so in pretty strong language, and indeed they have reacted since then.

Madam, that is all I think I need say by way of preface.

The Chairman: Thank you very much, Dr. Hare. We do appreciate your opening remarks. It is very interesting what you say about the Atomic Energy Control Board, questioning it. It is federal jurisdiction. We certainly have had them before the committee once, twice, or perhaps

[Translation]

Je vous avouerai en toute honnêteté que le système d'exploitation nous a laissés un peu inquiets. Comme nous le disons, nous croyons que Hydro-Ontario devrait l'examiner de plus près. Ce n'est pas qu'il y ait tellement de choses qui clochent dans ce système. Au contraire, si on le compare à ceux des autres pays et des autres services publics, comme nous l'avons fait en détail, c'est un bon système. Mais nous croyons qu'il contient les germes de son propre affaiblissement, et nous recommandons qu'ils l'examinent à nouveau. En fait, c'est ce qu'ils sont en train de faire.

Je dois dire qu'après avoir examiné Hydro-Ontario de près, on ne peut douter de la compétence technique et professionnelle de cet organisme. Quant à savoir si toutes les décisions économiques et importantes prises par cette société par le passé ont été sages est une autre question, mais ses performances techniques dans les domaines que nous avons étudiés méritent certainement à mon avis le respect international.

Pour ce qui est de la loi régissant ce domaine, elle relève de la compétence fédérale, mais nous avons décidé que cela ne nous arrêterait pas. Personne ne nous avait demandé d'examiner la Commission de contrôle de l'énergie atomique. Nous l'avons fait, et de nombreux groupes d'intervenants nous ont vivement recommandé de dire qu'il faudrait remplacer la bonne et neutre Commission de contrôle de l'énergie atomique par quelque chose qui ressemblerait davantage au modèle américain, dont le rôle consiste plutôt à prescrire des règlements et à s'occuper des questions juridiques qui opposent les parties. Nous en sommes venus à la conclusion que cela n'était pas nécessaire.

Mais les critiques à l'égard de la Commission de contrôle de l'énergie atomique, c'est-à-dire qu'elle a une interprétation trop étroite de son mandat. . . Oui, nous étions d'accord avec cela, nous l'avons dit et nous avons fait des recommandations quant à ce qui devrait arriver à la Commission; et j'espère que vous me poserez des questions à ce sujet. Après tout, il s'agit d'un domaine qui relève de la compétence fédérale; la sécurité des centrales nucléaires relève de la compétence fédérale. Même si j'ai reçu mon mandat du gouvernement provincial, j'ai décidé que je devais me mettre le nez dans les affaires du fédéral, quoi qu'il en soit.

Enfin, pour ce qui est des mesures d'urgence, nous en sommes venus à la conclusion que le gouvernement de l'Ontario n'avait pratiquement rien fait à ce sujet. Cela ne peut être toléré, et nous ne nous sommes pas gênés pour le dire, de sorte qu'ils ont effectivement réagi depuis.

Voilà qui complète, madame, mes remarques liminaires.

La présidente: Merci beaucoup, monsieur Hare. Nous vous remercions de ces remarques liminaires. Ce que vous dites au sujet de la Commission de contrôle de l'énergie atomique est très intéressant. Elle relève de la compétence fédérale. Elle a déjà comparu devant notre Comité une ou

[*Texte*]

three times. We have studied their mandate and feel there is a lot of room—in fact much room—for improvement.

• 1225

Mr. MacLellan: Thank you you very much for taking the time to be here today.

On your last remark, on the result of an emergency, that you felt the Province of Ontario was unprepared. . . and you say that situation has improved since then. What have they done, Dr. Hare, to correct this situation?

Dr. Hare: Nobody has told me, but I hear rumours that they have actually appropriated the funds necessary to put their own emergency plan into action, which they had not done up to the time of my report.

In effect, a nuclear emergency plan is a system of mobilization. You do not expect nuclear emergencies to occur. They are unlikely to occur. Hence what you need is a system of mobilization in which people have defined jobs to do; where the material resources exist to back it up, as, for example, the capacity in the hospital system to absorb a certain number of radiological casualties; and thirdly, where funds or resources are provided to create what amounts to stockpiles of equipment and skills that can be used in the event of an emergency.

All of this had been spelled out in detail by the Ontario Emergency Preparedness people, and in 1985 the province adopted a plan for dealing with nuclear emergencies, which is in some ways a model. It does all the things I think a plan ought to do. Then it sat.

When I reported to the government, there were just two people in the whole province working on this subject. There had been no action at all on the plan. It existed only on paper, in effect, outside the gates of the plants. Inside the plants, Ontario Hydro is well organized. It spends about $6 million a year just on standing by and waiting. But outside the gates, apart from some activity by the concerned municipalities and regions, such as the Durham region, which I am dealing with at the moment, no action had been taken to give any guts to this plan. It existed on paper; but I felt this was not good enough.

Mr. MacLellan: So really what they have done is they have requested the funds, and we really do not know what the actual details are.

Dr. Hare: No, we have no details.

Mr. MacLellan: On page 16 you said:

Because recent studies in England have nevertheless shown a possible association between lymphoid leukemias in persons under 25 years and proximity to

[*Traduction*]

deux fois, ou peut-être même trois fois. Nous avons étudié son mandat et nous en avons conclu qu'elle pourrait certainement faire beaucoup mieux.

M. MacLellan: Merci beaucoup d'avoir pris le temps de venir ici aujourd'hui.

En ce qui concerne votre dernier commentaire, sur ce qui arriverait en cas d'urgence, vous avez dit que la province de l'Ontario à votre avis n'était pas prête. . . et vous dites que la situation s'est améliorée depuis. Qu'ont-ils fait, monsieur Hare, pour corriger la situation?

M. Hare: Personne ne me l'a dit, mais j'ai entendu dire qu'ils ont en fait affecté les fonds nécessaires pour mettre en place leur propre plan d'urgence, ce qu'ils n'avaient pas fait lorsque j'ai rédigé mon rapport.

Un plan d'urgence en cas d'accident dans une centrale nucléaire est en fait un système de mobilisation. On ne s'attend pas à ce qu'un accident nucléaire survienne. Il est très peu probable qu'un tel accident se produise. Par conséquent, ce dont on a besoin, c'est d'un système de mobilisation selon lequel les gens ont quelque chose de défini à faire; où les ressources matérielles existent pour l'appuyer, par exemple la capacité du système hospitalier d'absorber un certain nombre de victimes d'accidents radiologiques. Troisièmement, c'est un système où des fonds ou des ressources sont alloués pour créer ce qui équivaut à des stocks de matériel et de compétences qui peuvent être utilisés en cas d'urgence.

Tout cela avait été expliqué en détail par le bureau ontarien de Protection civile Canada et en 1985 la province a adopté un plan pour faire face aux situations d'urgence nucléaires qui est, d'une certaine façon, un modèle. Il prévoit tout ce qu'un plan doit prévoir. Mais on n'y a pas donné suite.

Lorsque j'ai fait rapport au gouvernement, il n'y avait que deux personnes dans toute la province qui se penchaient sur cette question. Aucune mesure n'avait été prise pour donner suite au plan. Hors des murs des centrales, ce plan n'existait en fait que sur papier. À l'intérieur des centrales, Hydro-Ontario est bien organisée. Elle consacre environ 6 millions de dollars par année pour la seule prévention. Mais à l'extérieur des centrales, à part certaines activités des municipalités des régions intéressées, comme la région de Durham, dont je m'occupe en ce moment, aucune mesure n'avait été prise pour donner suite au plan. Il existait sur papier; mais à mon avis cela n'était pas suffisant.

M. MacLellan: Donc ils ont en fait demandé des fonds, et nous n'en connaissons pas réellement les détails.

M. Hare: Non, nous n'avons pas de détails.

M. MacLellan: À la page 16, vous dites:

Étant donné que des études récentes effectuées en Angleterre ont malgré tout démontré qu'il y avait un lien possible entre les leucémies lymphoïdes chez les

[*Text*]

nuclear installations, every effort should be made by epidemiological means to establish whether children or young adults in communities near reactors show increased leukemia incidence.

Is there anything to indicate that may be the case in Canada?

Dr. Hare: I am not aware of any evidence that suggests this, but prudence suggests that if an apparent association exists in England, it may exist here. The difference is that the English have very detailed health statistics, broken down very tightly by special units, and on the whole we do not. We have good statistics, but they are not refined spatially. Hence it is very difficult to make this kind of relationship clear in this country.

But before I made this report, the Atomic Energy Control Board had already agreed to do a feasibility study to see whether it would be possible to test our population for the same relationships. It is not obvious that it is possible. There are not very many people living near our nuclear plants, except at Pickering. In Britain, because of the population density, there is a large population that can be sampled everywhere on a very detailed basis. My suggestion to them was that they at least do this for Pickering and adjacent communities and for Deep River, just to see whether the statistics are parallel to the British experience.

Mr. MacLellan: From your own experience, though, are they somewhat parallel, other than in the proximity of the plants to the population?

Dr. Hare: No. Deep River is, of course, a nuclear community, and as far as I know there is nothing in the health statistics at Deep River to suggest that living there, close to Chalk River, has had any adverse effect upon them. The work force at Chalk River has been remarkably healthy. This includes the people who were exposed to the two severe accidents at Chalk River. So there is nothing in our record to suggest that there was any cause for alarm, but there is this report from the United Kingdom, which is the best report I have ever read in this area. It is quite literally true that all over the world where there are reactors people are looking at this and realizing it has to be at least sounded out for their own countries.

• 1230

The Chairman: Russell, we took our trip to Chalk River. Remember, they certainly were studying the people who worked there. It was remarkable.

[*Translation*]

personnes de moins de 25 ans et la proximité d'installations nucléaires, on devrait prendre tous les moyens épidémiologiques possibles pour déterminer si l'incidence de la leucémie est plus élevée chez les enfants ou les jeunes adultes vivant dans des collectivités qui se trouvent près des centrales nucléaires.

Y a-t-il quoi que ce soit pour indiquer que cela pourrait être le cas au Canada?

M. Hare: À ma connaissance, rien ne semble indiquer une telle chose, mais la prudence laisse supposer que s'il y a un lien apparent en Angleterre, il y en a peut-être un ici. La différence, c'est que les statistiques des Britanniques sont très détaillées dans le domaine de la santé, étant ventilées très exactement par unités spéciales, ce qui n'est pas le cas chez nous. Nous avons de bonnes statistiques, mais elles ne sont pas aussi détaillées. Par conséquent, il est très difficile d'établir clairement ce lien au pays.

Mais avant que je prépare mon rapport, la Commission de contrôle de l'énergie atomique avait déjà accepté de faire une étude de faisabilité pour voir s'il était possible de soumettre notre population à des tests pour établir s'il y avait ces mêmes liens. Il n'est pas évident que cela soit possible. Il n'y a pas un très grand nombre de personnes qui vivent près de nos centrales nucléaires, sauf à Pickering. En Grande-Bretagne, en raison de la densité de la population, il est possible de prendre un échantillon de la population un peu partout de façon très détaillée. Je leur ai donc suggéré de le faire au moins pour Pickering et les communautés adjacentes et pour Deep River, simplement pour voir si les statistiques sont comparables à celles de la Grande-Bretagne.

M. MacLellan: D'après votre propre expérience, cependant, elles sont en quelque sorte comparables, sauf pour ce qui est de la proximité des centrales par rapport à la population?

M. Hare: Non. Deep River est évidemment une communauté nucléaire, et que je sache, les statistiques n'indiquent aucunement que le fait de vivre à Deep River, près de Chalk River, puisse avoir des conséquences sur la santé de la population. Les employés de Chalk River sont remarquablement en bonne santé, y compris ceux qui ont été exposés aux deux accidents graves survenues là-bas. Rien dans nos dossiers n'indique qu'il y ait des raisons de s'inquiéter, mais il y a bien un rapport en provenance du Royaume-Uni et, à mon avis, c'est ce qui s'est fait de mieux dans ce domaine. Il s'est avéré que partout dans le monde où se trouvent des centrales, il y a des gens qui se penchent sur cette question, car ils se sont aperçu qu'il fallait à tout le moins s'en soucier pour leur pays.

La présidente: Russell, nous sommes allés à Chalk River. Rappelez-vous qu'il y avait évidemment des gens là qui étudiaient la chose. Cela sautait aux yeux.

[*Texte*]

Mr. MacLellan: Yes. It is funny they do not have more statistics, though. All that work and no statistics: it is unlike government agencies.

You mentioned the pressure tubes, sir, and you say on 29 that:

> I am not convinced there is no danger from public exposure, especially if the failure spreads to other fuel channels.

What exactly do you mean by that?

Dr. Hare: Of course, the inside of a calandria is a complicated place, as you know, with 380 or 480 of these tubes close to one another. So far in the two serious accidents that have taken place at Pickering and Bruce, the failure did not spread to other tubes.

There is some fear—or was rather than is, because it has largely been allayed now—that one of these bursts might be of such severity that the calandria tube might break and swing into its neighbours and produce a cascade of physical damage inside the reactor, which I suspect would then blow the reactor seal more rapidly, and I am not quite sure that would not break containment.

I have to say that this is leaning over backwards in the direction of caution, because almost unanimously my advisers say that will not happen. But I smelled a rat about this. I thought that, with all this pressure on all these tubes, it was not inconceivable there might be a muliplying break in the calandria that would start something that would break the containment.

It is worth remembering that the two breaks we are dealing with... As for the one in Pickering, we are dealing with a reactor with an exceptionally strong containment system. Even if it had been much worse, it would have been contained. In the newer reactors, because they have two shutdown systems, the containment is not quite as secure as that at Pickering. That is why I put in the remark, just to call attention to the fact that this is a serious problem that must not be overlooked simply because it has happened twice and has been contained.

Mr. MacLellan: You mentioned the importance of AECL and Ontario Hydro working together. It seems that Ontario Hydro, of course, is the beneficiary mainly of the expertise of AECL, and yet there are people questioning the role of AECL, which I think is still very important, and I gather from your report that you do as well. Perhaps you could give us your additional feeling on the importance of AECL, particularly its research and development work, to the role of Ontario Hydro.

[*Traduction*]

M. MacLellan: Oui. Il est curieux toutefois qu'il n'y ait pas plus de statistiques. Tout ce travail et pas de statistiques: c'est inusité pour un organisme gouvernemental.

Vous faites allusion aux tubes de force et vous dites à la page 29:

> Je ne suis pas convaincu qu'il n'y ait aucun risque d'exposition pour le grand public, surtout si une rupture s'étend à d'autres canalisations de combustible.

Au juste qu'entendez-vous par là?

M. Hare: Bien entendu, l'intérieur d'une calandre est une chose bien compliquée, comme vous savez, car elle comporte 380 ou 480 tubes serrés les uns contre les autres. Jusqu'ici, lors des deux accidents graves qui se sont produits à Pickering et à Bruce, la rupture ne s'est pas propagée à d'autres tubes.

On craint toujours—ou l'on craignait toujours, devrais-je dire, car cette crainte s'est en majeure partie dissipée—qu'il y ait une rupture tellement importante qu'elle puisse se propager aux tubes de la calandre et aux tubes avoisinants, de manière à produire une séquence de dégâts matériels au sein du réacteur, et j'ai à l'idée que cela pourrait faire sauter la gaine du réacteur plus rapidement, et je doute que l'enceinte de confinement puisse alors rester intacte.

Je dois ajouter qu'il s'agit d'un cas extrême contre lequel il faut se prémunir, car presque tous mes conseillers me disent que la chose est impossible. Mais cela m'a mis la puce à l'oreille. Vu l'immense pression qui s'exerce sur tous les tubes de force, il ne me semble pas inconcevable qu'il y ait une rupture multiple dans la calandre, ce qui pourrait entraîner des dommages à l'enceinte de confinement.

Il importe de se rappeler que les deux ruptures dont nous parlons... Pour ce qui est de Pickering, le réacteur qui s'y trouve est doté d'une enceinte de confinement exceptionnellement résistante. Même si la rupture avait été beaucoup plus grave, l'enceinte de confinement serait restée intacte. Dans les nouveaux réacteurs, vu l'existence d'un double système d'arrêt, l'enceinte de confinement n'offre pas le même degré de difficulté que celle de Pickering. Voilà pourquoi j'ai inséré cette remarque, simplement pour signaler qu'il s'agit d'une grave éventualité qu'il ne faut pas négliger tout simplement parce que l'on a pu limiter les dégâts lors de deux accidents antérieurs.

M. MacLellan: Vous dites qu'il est important que l'EACL et Hydro-Ontario puissent collaborer. Il me semble évident qu'Hydro-Ontario est l'organisme qui profite le plus des connaissances techniques de l'EACL; pourtant, certains contestent encore le rôle de l'EACL, qui est fort important, à mes yeux, chose que vous laissez aussi entendre dans votre rapport. Vous pourriez peut-être développer votre pensée quant à l'importance de l'EACL, notamment de ses travaux de recherche et de développement, pour le bon fonctionnement d'Hydro-Ontario.

[*Text*]

Dr. Hare: I may say by way of preface that there certainly is not any great amount of love lost between the technical staffs of these two bodies. You hear a lot of criticism of AECL at Ontario Hydro, whereas I have not heard AECL people binding about Hydro. But I certainly have heard Hydro men taking AECL apart.

So I did not put these remarks in here because I wanted to please Hydro. I think Hydro would enjoy the feeling of self-sufficiency. I also think it is one of Hydro's weaknesses that they have this feeling, that they like to be self-sufficient, and the report contains formal recommendations that they would be better off if they had a broader contact with the scientific and technical community.

Now, specifically as regards AECL, the experimental facilities that AECL have, particularly at Chalk River but also to a large extent at Whiteshell, are completely fundamental to such kinds of research as, for example, fuel channel research. It is true that there is fuel channel research in progress in Hydro's own labs on Kipling Avenue in Toronto. It is true that certain facilities exist at Canadian Westinghouse, and used to exist in Canadian General Electric, where similar fuel channel research could be undertaken. But the major centre—and it is the major world centre of research in this area—is Chalk River, with a notable assist from Whiteshell.

• 1235

If there is any question at all about not only the safety of the present fuel channel installations but indeed the calandria and the reactors generally, then it has to be answered not really in Hydro facilities but in AECL's labs.

It is not just a question of the role of the research corporation, the research company. Some of the work in the AECL engineering labs is work that is pretty fundamental to the proper operation of CANDU reactors, including such things as remote control inspection systems for pressure tubes, the SLAR program.

So I see AECL's role as absolutely crucial to not only the future economic basis of Hydro but public safety itself, which is why I find it hard to be very sympathetic towards the rather, I think, heavy-handed reductions in expenditure the federal government has entered into with AECL. I do not approve of those reductions.

I do approve of there being a relationship between the amount of expenditure that we are prepared to admit is right for AECL and our ability to sell reactors overseas. I am not a salesman and I neither want nor "unwant" to sell reactors; but I am very much concerned with the safety, security, and performance of our own reactors, and

[*Translation*]

M. Hare: Je dirai, en guise de préface, que les relations entre le personnel technique de ces deux organismes ne sont pas manifestement des plus amicales. On entend beaucoup de critiques de l'EACL à Hydro-Ontario, quoique je n'aie pas entendu des gens de l'EACL se plaindre d'Hydro-Ontario. Chose certaine, toutefois, il y a des gens d'Hydro-Ontario qui s'en prennent à l'EACL.

Je n'ai toutefois pas inscrit ces remarques afin de faire plaisir à Hydro-Ontario. Je crois qu'Hydro-Ontario serait ravie de se sentir autonome. J'estime aussi que c'est là l'une de ses faiblesses, ce désir d'être autonome, voilà pourquoi, dans les recommandations officielles qui figurent dans mon rapport, j'affirme qu'il serait dans l'intérêt d'Hydro-Ontario de multiplier ses contacts avec la collectivité scientifique et technique.

Plus précisément, en ce qui a trait à l'EACL, les installations expérimentales dont elle dispose, notamment à Chalk River mais aussi, dans une grande mesure, à Whiteshell, sont tout à fait essentielles à ce genre de recherche, comme les travaux sur les canalisations de combustible, par exemple. Il est vrai que de tels travaux de recherche se déroulent présentement dans les laboratoires d'Hydro-Ontario sur l'avenue Kipling à Toronto. Il est vrai que certaines installations se trouvent à Canadian Westinghouse et se trouvaient jadis à Canadian General Electric, où des travaux de ce genre peuvent être effectués. Mais le principal centre de recherche—et c'est l'un des plus importants au monde dans ce domaine—se trouve à Chalk River, avec un appoint notable de la part de Whiteshell.

Si quelque doute subsiste quant à la sécurité non seulement des canalisations actuelles de combustible mais aussi des calandres et des réacteurs en général, il sera dissipé non pas dans les installations d'Hydro-Ontario, mais dans les laboratoires de l'EACL.

La question ne se résume pas simplement à ce rôle de la société en matière de recherche. Certains des travaux de génie qu'elle effectue dans ses laboratoires revêtent un aspect essentiel pour le bon fonctionnement des réacteurs CANDU, entre autres choses, ces régimes d'inspection à télécommande pour les tubes de force, le programme SLAR.

Pour moi, le rôle de l'EACL est absolument crucial non seulement pour la stabilité économique d'Hydro-Ontario, mais aussi pour la sécurité publique elle-même, voilà pourquoi j'ai beaucoup de mal à accepter les compressions budgétaires, bien maladroites, à mon avis, que le gouvernement fédéral a imposées à l'EACL. Je ne peux approuver ce geste.

Ce que j'approuve, c'est qu'il y ait un lien entre les dépenses que nous permettons à l'EACL de faire et notre capacité à vendre des réacteurs à l'étranger. N'étant pas vendeur, je ne suis ni pour ni contre la vente de réacteurs, mais je m'intéresse de très près à la sécurité et au rendement de nos propres réacteurs, qui dépendent

[*Texte*]

that depends heavily on facilities that are at present financially strapped because of federal action.

It is not entirely the federal government's fault—do not get me wrong. It is just that, it seems to me, there is a jurisdictional hang-up here that needs straightening out.

The Chairman: Is that not interesting, because it almost makes me believe that you have been listening to some of our in camera meetings. We have exactly the same feelings and concerns.

Mr. Porter: Dr. Hare, may I welcome you, too, on behalf of the committee. We have looked forward to having you appear before us today.

I have a number of questions I would like to ask as a result of the report; but, before I do, we have had people appear before this committee and the committee has travelled and I think we have all been impressed by some of the facilities and the safety standards we have seen. We have had groups before us who have indicated that they are trying to make the public as aware as they can of the progress that is being made in this way.

Yet I guess an example was on television last night. I do not know whether you saw *The Journal*, where a company called Airco was hauling supposedly contaminated rock—it was in Quebec—that was being used for road surfacing and even in some areas of construction. It does very little to instil much confidence in the public when they see something like that. I do not know how much truth is in that and how much danger there could have been, but certainly there is apprehension among the general public and we seem to be going to a lot of pains to make sure that facilities, the handling of materials, and the use we are going to require of nuclear power in the future are going to be readily available.

I do not know whether you wish to comment on that before I touch on some of the areas where you may wish to, and I do not know whether you are aware of that situation.

Dr. Hare: I had not come across that particular one, but almost every day something happens. To anyone who does not know the difference between one kind of radioactive operation and another, it sounds terrible—and indeed sometimes is terrible. There is no question that it is very hard to maintain discipline throughout this industry.

• 1240

Of course, I was talking about Ontario Hydro, its central reactor operations, and at that level the discipline is quite excellent, and the training is excellent. At the other end, the trucking end, of loose ores and aggregates,

[*Traduction*]

énormément des installations qui subissent présentement le contrecoup de ces compressions budgétaires imposées par le fédéral.

Il ne faut pas en imputer entièrement la faute au gouvernement fédéral—comprenez-moi bien. C'est tout simplement qu'il me semble y avoir un malentendu en matière de compétence qu'il faudra bien dissiper un jour ou l'autre.

La présidente: Vous m'intriguez, car l'on pourrait presque croire que vous avez assisté à quelques-unes de nos réunions à huis clos. Nous avons exactement le même sentiment et les mêmes appréhensions.

M. Porter: Monsieur Hare, je tiens moi aussi à vous souhaiter la bienvenue au nom du Comité. Nous attendions avec impatience votre témoignage d'aujourd'hui.

Il y a un certain nombre de questions que j'aimerais poser, suite à la présentation du rapport; mais auparavant, je dirai que tous les membres du Comité, qui ont entendu d'autres témoins et qui ont fait la tournée, ont été impressionnés par quelques-unes des installations et des normes de sécurité dont ils ont pris connaissance. Il y a même certains groupes qui nous ont laissé entendre qu'ils s'efforçaient le plus possible de faire connaître au grand public les progrès qui ont été réalisés dans ce domaine.

Par ailleurs, je songe à des choses comme l'émission télévisée que j'ai vue hier soir. J'ignore si vous avez vu cela à *The Journal*, mais on parlait d'une société appelé Airco qui apparemment extrairait des roches contaminées—c'est au Québec—que l'on emploie ensuite pour le revêtement des routes et pour certains travaux de construction. Cela ne peut qu'inspirer de la méfiance dans l'esprit des gens qui voient cette chose-là. J'ignore dans quelle mesure ce reportage est exact, s'il y avait effectivement des risques, mais chose certaine, cela suscite des appréhensions chez le grand public, alors que nous déployons apparemment beaucoup d'efforts à l'égard des installations nucléaires, de la manutention des matériaux, des usages de l'énergie nucléaire que nous cherchons à répandre.

Peut-être voudriez-vous commenter ce fait avant que je n'aborde les questions qui vous intéressent plus précisément; je me demande si vous êtes au courant de cette situation.

M. Hare: J'ignorais tout de cette situation, masi il se passe quelque chose de semblable presque tous les jours. Pour ceux qui ne peuvent distinguer entre les diverses formes d'exploitation des matériaux radioactifs, cela peut sembler horrible—et cela l'est parfois. Il ne fait aucun doute qu'il est bien difficile de maintenir la discipline au sein de l'industrie.

Bien entendu, je parlais d'Hydro-Ontario, de son exploitation du réacteur central, et à ce niveau la discipline et la formation sont excellentes. À l'autre extrême, au niveau du transport par camion du minerai et

[*Text*]

while I do not know very much about it, it is quite clear it is not always as tight as it should be.

Mr. Porter: I just point that out because I think it was a perception of the public, and they are not going to differentiate. It is just another type of thing that I think is of concern to them.

In your recommendations on page 4 you mention there are complaints that upward-directed safety recommendations are not always acted upon. Are you suggesting that senior officials do not take action on some of the recommendations provided to them? Is that what you meant by upward-directed safety recommendations?

Dr. Hare: Yes. I put a team of industrial consultants—not from the nuclear industry—into the reactors and asked them to report on how it was done. I also talked to spokesmen from the unions. Both my consultants and some of the union people who spoke to me complained about the fact that from time to time what they regarded as useful and valid suggestions concerning safety were sent upwards and that was the last they ever heard of them; they seemed to disappear into thin air.

Ontario Hydro has a body called the Nuclear Integrity Review Committee, NIRC, headed by Bill Morrison, who is their senior nuclear engineer and a very greatly respected international figure. Hydro insisted that every such complaint would reach the ears of this committee and be investigated. But the union men that I spoke to actually denied they knew of the existence of this committee. We got the feeling that all was not absolutely well about the upward-reporting techniques. I am making allowance for the fact that unions generally do not say anything good about management and vice versa.

Even allowing for that, we got the feeling there was a need to shake the system up a bit. Knowing Ontario Hydro, I am quite certain that remark has already torn around the place. They respond to criticism very rapidly indeed. By the way, Ontario Hydro will be publishing a response volume to these criticisms very shortly.

Mr. Porter: I assume they would respond too where you have said there appear to be undesirable differences in safety systems and radiological performance between stations. Is there not a prescribed safety standard across the board between stations?

Dr. Hare: Oh, yes. Of course, what happens is that the Atomic Energy Control Board sets standards in the shape of such things as levels of worker exposure that may not be exceeded, levels of emission of radioactive materials that may not be exceeded so as to protect the public, and generally the reactors operate far below these limits voluntarily. In general, in most of these areas, the effort is to operate at no more than 1% of the permitted limit, so

[*Translation*]

des agrégats, quoique je connaisse bien peu de choses à ce sujet, il me semble évident qu'un certain relâchement inacceptable puisse se produire.

M. Porter: Je le signale tout simplement parce que c'est ainsi que le grand public voit la chose, sans prendre la peine de faire des distinctions. C'est l'un des aspects de cette question qui semble préoccuper les gens.

Dans vos recommandations à la page 4, vous dites que l'on se plaint que les mesures de sécurité qui y sont préconisées sont parfois laissées sans suite à un niveau supérieur. Faut-il entendre que les cadres supérieurs ne donnent pas toujours suite aux recommandations qui leur sont transmises? Est-ce cela que vous entendez par recommandations de sécurité à un niveau supérieur?

M. Hare: Oui. J'ai demandé à une équipe d'experts-conseils—non pas du secteur nucléaire—d'examiner la question des réacteurs et de me préparer un rapport à ce sujet. J'ai aussi eu des entretiens avec les porte-parole des syndicats. Tant ces experts-conseils que certains délégués syndicaux se sont plaints à moi que, dans certains cas, les propositions qu'ils jugeaient utiles et valables en matière de sécurité avaient été transmises aux autorités, mais qu'ils n'en avaient plus jamais entendu parler par la suite; elles semblaient s'être volatilisées.

Hydro-Ontario s'est doté d'un organisme appelé le Comité d'examen de l'intégrité nucléaire, le CEIN, que préside le principal ingénieur nucléaire, M. Bill Morrison, qui jouit d'une grande réputation internationale dans ce domaine. Hydro-Ontario soutient que toute plainte valable est transmise à ce comité et fait l'objet d'une enquête. Mais les délégués syndicaux à qui j'ai parlé m'ont déclaré qu'ils ignorent l'existence de ce comité. Nous avons eu le sentiment que tout ne marche pas très bien pour ce qui est de l'acheminement des requêtes aux paliers supérieurs. Je tiens compte du fait que les syndicats et la direction ont le plus souvent des reproches mutuels à se faire.

Même à cela, il nous a semblé que certains changements s'imposent. Connaissant Hydro-Ontario, je n'ai aucun doute que cette remarque a déjà fait le tour des lieux. Elle réagit fort promptement aux reproches qui lui sont formulés. Soit dit en passant, Hydro-Ontario publiera sous peu une brochure renfermant sa réponse à ces critiques.

M. Porter: J'imagine qu'elle aura un mot à dire quant aux divergences peu souhaitables que vous avez relevées dans les systèmes de sécurité et le rendement radiologique des diverses centrales. N'y a-t-il pas des normes de sécurité prescrites pour toutes les centrales.

M. Hare: Oui, bien sûr. En fait, c'est la Commission de contrôle de l'énergie atomique qui fixe les normes pour diverses choses, telles les doses limites d'exposition au rayonnement pour le personnel, les doses limites de libération de radioactivité pour la protection du grand public et, en général, les réacteurs fonctionnent volontairement bien en-deçà de ces limites. Dans la plupart des cas, en général, on s'efforce d'atteindre pas

[*Texte*]

they have two orders of magnitude. In other words, they have two zeros of freedom there because they are well below the permitted limit. That is the general principle.

Some stations, we noticed, consistently did better than that. Pickering "B", for example, and Bruce "B" quite often are operating in three or four of these domains at only about one-thousandth of the level which is legally permitted, which is a really excellent performance. On the other hand, Bruce "A" in some respects operates right up to the permitted level or close to it, and we could not see why such differences should exist, nor could I get any good explanation as to why they existed.

That is the basis for that paragraph. I was dissatisfied by what appeared to be managerial differences between stations that were tolerated, and I thought they should be removed and looked at, which is why I recommended that Ontario take a look at this. Incidentally, I can again confirm that they are doing so. I have had a lot of dealings with Hydro since then.

• 1245

Mr. Gagnon: Dr. Hare, I am certainly delighted to have a person of your stature address us. Would you put your professional qualifications on the record, some of the things you have done in your career—that is, prior to becoming chancellor at a salary of zero dollars a year?

Dr. Hare: I am afraid I have done a large number of things. I am 69 years old, and there has been plenty of time to cram a lot in.

By profession, I am an atmospheric scientist and university teacher. I am a climatologist. My major research interest, my concentration in the last few years, has been in the Greenhouse Effect. I am chairman of the Advisory Group on Greenhouse Gases of the UN System. That has been my major interest through many years of life.

However, something like 12 years ago I began a series of public inquiries of this sort, not because I wanted to but because I was asked to. The Minister of Energy, Mines and Resources asked me to look at the nuclear waste disposal issue in 1977, not because I knew anything about it but because I did not. I had a reputation outside and they wanted to get an external look.

Since that time, largely through the Royal Society of Canada, I have conducted public inquiries or scientific inquiries into a whole variety of things. For example, in the acid rain field, the acid deposition field, I was the Canadian chairman of the joint committee of the two academies across the border on this subject for two years. I was the chairman of the Canadian Peer Review Panel under the Canada-U.S. Memorandum of Intent to reduce trans-boundary air pollution. Bill Nierenberg was the

[*Traduction*]

plus de 1 p. 100 des doses limites prescrites, ce qui donne deux ordres de grandeur. Autrement dit, on jouit d'une énorme latitude en s'en tenant à un tel pourcentage en-deçà des doses limites. Voilà le principe qui est généralement suivi.

Nous avons constaté que certaines centrales atteignent largement cet objectif. Ainsi, Pickering «B» et Bruce «B» fonctionnent bien souvent, dans trois ou quatre de ces domaines, à seulement un millième du niveau de la dose limite légitime, ce qui constitue un excellent rendement. D'autre part, Bruce «A», à certains moments, atteint, à peu de choses près, la dose limite de fonctionnement prescrite, et nous ne pouvons comprendre pourquoi de telles divergences existent, et nous n'avons pas reçu de bonnes explications à cet égard.

Voilà la raison d'être de ce paragraphe. Je n'admets guère que l'on puisse tolérer de telles divergences au niveau de la gestion des diverses centrales. Je crois qu'il faudrait examiner la situation et tenter de les éliminer; voilà pourquoi j'ai fait cette recommandation à Hydro-Ontario. Soit dit en passant, je peux vous confirmer que c'est ce qu'elle fait en ce moment. Depuis lors j'ai eu de nombreux contacts avec Hydro-Ontario.

M. Gagnon: Je suis enchanté que nous ayons l'occasion de nous entretenir avec vous car nous savons tous bien entendu que vous êtes une personnalité de premier plan. Pourriez-vous nous dire brièvement ce que vous avez fait avant de devenir chancelier, poste qui ne comporte aucun salaire?

M. Hare: J'ai fait énormément de choses. Comme j'ai déjà 69 ans, j'ai eu une vie bien remplie.

Je suis un spécialiste des sciences de l'atmosphère et de la climatologie et j'ai enseigné à l'université. Depuis quelques années, je m'adresse plus particulièrement à l'effet de serre et je suis d'ailleurs le président du groupe consultatif de l'ONU sur l'effet de serre. C'est une question qui me passionne depuis de nombreuses années.

Il y a une dizaine d'années environ, j'ai été invité à mener des enquêtes publiques. En 1977, le ministre de l'Énergie, des Mines et des Ressources de l'époque m'a invité à étudier la question de l'évacuation des déchets nucléaires, question que j'ignorais d'ailleurs, mais il s'agissait justement d'avoir l'avis d'un spécialiste impartial.

Depuis lors j'ai mené toute une série d'enquêtes scientifiques dans différents domaines, essentiellement par le truchement de la Société royale du Canada. Ainsi je suis le président canadien du Comité mixte des académies canadienne et américaine chargé d'étudier les pluies acides. J'ai également présidé le groupe canadien chargé de vérifier des accréditations dans le cadre du protocole d'entente Canada-États-Unis en vue de la réduction de la pollution atmosphérique transfrontalière. M. Bill

[*Text*]

American co-chairman. Then at Joe Clark's request I did the Canadian Public Study of the Nuclear Winter Phenomenon. That was the document that went to the UN General Assembly. Mr. Clark tabled it there. I was for two years the chairman of the Royal Society's Commission on Lead in the Canadian Environment.

So what I have become is a sort of general-purpose investigator of scientific things. I am not a nuclear scientist and I have absolutely no connection with this industry. I have never set foot inside the houses or the offices of any member of the industry or ever accepted a drink from one of them. So my hands are clean.

But this is the second time I have had a really very deep look at the nuclear industry; and I must say it has been a very worthwhile thing to do.

Mr. Gagnon: That is certainly a fascinating background. If we could ask you for some of your expertise, one of the areas we are grappling with. . . and it looks as if the four members present today all come from areas of fossil fuel. Speaking for myself, when I started this study, if my bias was known, it would probably be anti-nuclear, pro-fossil fuel. I have certainly reversed my position, just because of the Greenhouse Effect and these sorts of problems that we are getting into.

What is your feeling on where the world should be going politically, nuclear versus fossil fuel versus conservation?

Dr. Hare: I do not think governments or private corporations have any business forcing technologies people do not accept down their throats. If the public will not accept the nuclear technology, then I will not advocate it. On the other hand, I personally believe nuclear technology as practised in this country can be kept safe and the public can be adequately protected, and is adequately protected at the present time. That is a personal belief. Hence, within the kind of democracy we are, I guess you could say personally I am pro-nuclear. But I am not an advocate, in that I do not go out and try to get people to build more reactors. I think that is incompatible with the work I do, which is to try to be scientifically objective about things.

• 1250

I am not hopeful that the world will abandon the fossil fuels. As an atmospheric scientist, I think the fossil fuels are a real danger to the world environment. There does not seem to me to be any escape from it. I drove here, Madam Chairman, emitting carbon dioxide along the entire road, and even though my car is a new one and has the proper catalytic filters on it, there is some charge on the environment that the car makes at every stage of the way, and I do not see how we can escape from that for a very long time to come.

The world is going to be dependent on the fossil fuels, and even if other countries could develop a stabilized nuclear industry of the sort we have, with very high

[*Translation*]

Nierenberg était le coprésident américain. À la demande de M. Joe Clark, j'ai mené l'Enquête canadienne sur le phénomène de l'hiver nucléaire, document qui a ensuite été communiqué à l'Assemblée générale de l'ONU. C'est M. Clark lui-même qui l'a déposé. Pendant deux ans, j'ai assuré la présidence de la Commission de la Société royale sur le plomb dans l'environnement canadien.

Je suis disons en quelque sorte devenu l'enquêteur tout azimuts des questions scientifiques. Par contre je ne suis pas spécialiste des questions nucléaires et je n'ai aucun contact avec ce secteur. Je n'ai jamais eu de contacts quels qu'ils soient avec des représentants de l'industrie nucléaire et je suis donc parfaitement objectif à cet égard.

Toutefois c'est la deuxième fois que j'ai l'occasion d'examiner le dossier de l'industrie nucléaire, travail que j'ai d'ailleurs beaucoup apprécié.

M. Gagnon: Vous avez effectivement une énorme expérience. Il se fait justement que les quatre membres du Comité qui assistent à cette réunion représentent des circonscriptions qui possèdent des gisements de combustible fossile. Moi-même au début de cette enquête j'étais plutôt anti-nucléaire et en faveur des combustibles fossiles. Depuis lors j'ai changé d'idée à cause, entre autres, de l'effet de serre.

À votre avis, le monde devrait-il opter pour l'énergie nucléaire plutôt que pour les combustibles fossiles ou encore plutôt pour la conservation?

M. Hare: Une technologie ne devrait jamais être imposée de force ni par l'État ni par les entreprises. Si la société n'est pas prête à admettre l'énergie nucléaire, il ne m'appartient pas d'en prendre la défense. Pour ma part, j'estime néanmoins que la technologie nucléaire telle qu'on la pratique au Canada est sans danger et que le public n'a rien à craindre. Donc on peut dire que personnellement je suis en faveur du nucléaire. Mais l'idée ne me viendrait pas de me faire le champion du nucléaire ni de parler en faveur de la construction de nouvelles centrales. Ce serait en effet contraire à l'objectivité scientifique que je cherche à maintenir.

J'espère cependant que les combustibles fossiles seront abandonnés partout dans le monde car ils constituent un danger réel pour l'environnement. Il n'y a d'ailleurs pas moyen d'y échapper. Ainsi, pour me rendre à Ottawa, j'ai pris ma voiture qui, bien qu'étant toute récente et donc équipée de filtres catalytiques, émet néanmoins du gaz carbonique qui s'échappe dans l'atmosphère.

Le monde continuera pendant longtemps encore à dépendre des combustibles fossiles même si d'autres pays parviennent à se doter d'une industrie nucléaire conforme

[*Texte*]

technical standards—and I may say I think the French have done that, and the British have done it very successfully, but other countries have been less fortunate, and the Americans are among that group. But even if everybody could agree that nuclear technology can be made and kept safe, you still could not make it the primary source of electrical power. Even if you made it the source for as much electric power as you could, you still have the problem of the mobile fuels.

I am aware, of course, of the research that is being done on hydrogen as an atmospheric carrier, but then as an energy carrier that in itself presupposes that you have a source with which to dissociate the water in the first place, and the only source that seems to be available to us on any very large scale is the nuclear source.

I thank my lucky stars, Mr. Gagnon, that I am a scientist and you are a politician. You have to make the choice and I do not. It is a very difficult choice.

Mr. Gagnon: If we could turn our attentions to some of the points you have raised, Atomic Energy Control Board, one of the issues we have been wrestling with is the position of AECB and AECL on such things as setting up a high level repository for the spent fuel. Does the AECB currently set the guidelines as to what radiation background should be allowed?

Dr. Hare: There is a consultative document which sets the board guidelines, but the whole philosophy of the board is that it does not specify exactly how this is to be done. And since nobody has ever yet created a repository, this remains very much in the indefinite stage, as far as I understand it.

But the board certainly should be the body that sets the criteria that have to be met, and I think those criteria will be rather close to the consultative documents that are now floating around. There is a lot of experience worldwide, of course, about this question and there is no reason why the board should not have a firm opinion about it.

Mr. Gagnon: Do you feel the directorship of the board should be increased?

Dr. Hare: Yes. I think perhaps my most crucial feeling about regulation in this whole business is that the Atomic Energy Control Board is too small. When I compare it with the regulating bodies in other countries, I am amazed with what they do, but at the same time I do not think this can continue.

You have to remember that two members of that board are there *ex officio* anyway. The president of the board itself, AECB, is *ex officio* a member. The president of the National Research Council is *ex officio* a member. And with the best will in the world, Larkin Kerwin does not have time to sit down there day after day acting as somebody else's watchdog. So you are down to three people who have some degree of freedom in considering these questions.

[*Traduction*]

aux normes très strictes comme la nôtre, ce qui est également le cas pour la France et la Grande-Bretagne; par contre, d'autres pays dont les États-Unis n'ont pas si bien réussi. Mais même si tous les pays pouvaient se mettre d'accord sur l'énergie nucléaire, celle-ci ne peut pas devenir la source principale de l'électricité dont nous avons besoin. Et même si c'était possible, reste toujours le problème des combustibles utilisés par les véhicules à moteur.

Pour obtenir de l'énergie à partir de l'hydrogène, il faut commencer par dissocier l'hydrogène et l'oxygène de l'eau, ce qui exige énormément d'énergie dont la seule source actuelle est justement l'énergie nucléaire.

Je remercie le sort de ne pas être un homme politique et donc de ne pas être acculé à faire des choix, car ce serait extrêmement difficile pour moi.

M. Gagnon: Il a été question de la position de la Commission de contrôle de l'énergie atomique et de l'EACL en ce qui concerne les modalités d'évacuation du combustible usé. Est-ce la Commission de contrôle qui fixe les directives en ce qui concerne les niveaux de radiation autorisés?

M. Hare: La Commission a effectivement des directives sans pour autant préciser comment elles doivent être mises en oeuvre. D'ailleurs, comme il n'existe pas jusqu'à présent d'endroits pour l'évacuation de ces déchets, aucune mesure pratique n'a encore été arrêtée.

Mais en principe, c'est certainement la Commission qui devrait établir les critères à respecter, critères qui se rapprocheront sans doute de ceux qui figurent dans les documents consultatifs. La Commission pourrait d'ailleurs énoncer un avis à ce sujet en se fondant sur les connaissances scientifiques les plus récentes recueillies de par le monde.

M. Gagnon: Le nombre d'administrateurs qui siègent à cette commission devrait-il être accru?

M. Hare: Certainement, car j'estime que la Commission de contrôle de l'énergie atomique comporte bien trop peu de membres. En effet, dans d'autres pays, ces commissions comportent bien plus de spécialistes que chez nous, ce qui rend d'ailleurs le travail réalisé par la Commission canadienne d'autant plus étonnant mais cela ne peut pas durer.

De toute façon, deux membres de la Commission sont membres d'office. Ainsi le président de la Commission est membre d'office, de même que le président du Conseil national de recherche. Or, M. Larkin Kerwin, même s'il y met la meilleure volonté du monde, ne peut pas tout faire en même temps. Il ne reste donc plus que trois membres de la Commission qui puissent vraiment se pencher sur ces questions.

[Text]

Moreover, it is quite clear to me that in making its decisions the board ought to take into account far more broadly than it can do at the present time socio-economic, radiological and environmental questions for which the board members themselves have very little skill. So in my report I recommend that the size of the board be increased so as to make such broader representation possible.

I also say, Madam Chairman, that I think the board should remain a technical regulator. But what I am saying is that those technical regulations should have been made by a board that is competent around the table to consider more deeply the socio-economic, health and environmental questions which are the real stuff of this business. The technical questions are not usually in doubt; it is the non-technical matters that really have to be discussed in depth, and they have been inhibited from doing this. Moreover, it has been their policy to avoid this. There is a tendency for a natural scientist to say, we will not sully ourselves by touching these more difficult questions. That goes all the way back to C.J. MacKenzie, I may say, and I cannot agree with that.

• 1255

Mr. Gagnon: What sort of numbers for the board would you suggest?

Dr. Hare: I suggested in one draft of the report, and I was persuaded to take it out by my review panel, which I may say is the toughest review panel anybody has ever had to get past—I said three more members.

Mr. Gagnon: Three full-time or three part-time members?

Dr. Hare: That is another point I must raise separately. Three more members on the present basis. But I also feel that the board needs full-time members. I think in that respect the Americans are right with the Nuclear Regulatory Commission. They recognize the full-time principle.

What I am saying is to increase the board membership to eight from five. I do not say that in this report. That is what I would have said if I had not had any advisers. Then I would also say, at least four of those full time, with the obligation to take on one of the major sectors in support of the president's work. At the moment he has to be everything, and he cannot be.

For one thing, I think they should be very much more visible, Madam Chairman. Nobody knows the AECB exists. It is a very good regulator. This country's record, there is no question about it, is one of the best in the world, and it has been achieved by these people. But absolutely nobody knows this. How the public can have confidence in a body that they do not know exists. . . Well, perhaps that is the way to have confidence in a body.

[Translation]

Avant de rendre ses décisions, la Commission devrait prendre en compte plus qu'elle ne le fait actuellement des facteurs socio-économiques ainsi que des facteurs de l'écologie et de la radiologie, questions qui ne sont justement pas de la compétence des membres de la Commission. Je recommande donc dans mon rapport d'augmenter le nombre de membres de la Commission afin d'avoir justement des experts dans tous ces domaines.

J'estime par ailleurs que la Commission devrait continuer à s'occuper de la réglementation, mais à la condition que les membres de la Commission soient qualifiés pour se prononcer sur des questions socio-économiques, sur les questions de santé et de l'environnement qui sont au coeur même du problème. Ce ne sont pas les questions techniques qui font problème mais plutôt les questions non techniques qui doivent être examinées en détail et c'est ce qui a été difficile la plupart du temps. D'ailleurs les scientifiques ont tendance à prendre les questions non techniques de haut et à les laisser à d'autres. C'est une tradition qui remonte à C.J. MacKenzie, et que je n'approuve pas.

M. Gagnon: Qui, à votre avis, devra faire partie de la Commission?

M. Hare: Dans mon projet de rapport, je voulais proposer que trois autres personnes soient nommées à la Commission, mais mon comité de révision, qui est, soit dit en passant, le plus sévère des organismes de ce genre, m'a convaincu de retirer cette proposition.

M. Gagnon: Trois personnes à plein temps ou à temps partiel?

M. Hare: Trois nouveaux membres dans les conditions actuelles. Mais j'estime par ailleurs que les membres de la Commission devraient travailler à temps plein comme c'est le cas notamment pour la «Nuclear Regulatory Commission» des États-Unis.

Le nombre de membres de la Commission devrait donc passer de cinq à huit. Comme je le disais, vous ne trouverez pas cette recommendation dans le rapport; elle y serait n'eût été de mes conseillers. Et sur ces huit, donc, quatre au moins devraient travailler à temps plein et se charger d'un des principaux secteurs qui tous actuellement relèvent du président, dont la charge est trop lourde.

J'estime en outre que la Commission de contrôle devrait être mieux connue et elle le mérite d'ailleurs vu que grâce au bon travail de ses commissaires, le Canada a l'une des meilleures traditions de sécurité nucléaire au monde. Or pratiquement personne ne connaît la Commission. Comment voulez-vous que les gens fassent confiance à une Commission dont ils ignorent jusqu'à l'existence?

[*Texte*]

Mr. Gagnon: On page 21 you say that the annual report of the AECB should receive more than nominal scrutiny by the appropriate parliamentary committee. What exactly did you have in mind here?

Dr. Hare: When the annual report of the board is tabled, according to my reading of the committee documents which I was provided with, it gets an average of two hours' inspection by a parliamentary committee. I think it requires two months of inspection. Is this the committee that does the inspection? Well, forgive me if I sound rude, Madam Chairman.

The Chairman: Not at all. This is very interesting for us to hear.

Dr. Hare: I personally feel that the report of the board is a crucial document in the maintenance of public safety, that the board should have for the period of an inspection a professional consultant, in that area concerned, from outside the Atomic Energy Control Board, or indeed from outside the Canadian nuclear industry, and that AECB officials should be asked to justify what they have done. It would be an invaluable way of sharpening up the whole question of the role of Parliament in this.

If I could go just a little further, I feel that Parliament not only has an absolute obligation to play this role of a much tougher inspector of its autonomous bodies, commissions, in the environmental area, but it also has some obligation to instruct those bodies far more than is done at the present time.

If I may illustrate what I mean by that, the Atomic Energy Control Board, early in its days, came to the conclusion that a risk to the public of something of the order of between 1 in 100,000 or 1 in 10 million hazards was the appropriate level to aim at in designing the safety of the Canadian reactor systems. I think that decisions of that kind belong in Parliament and not with the Atomic Energy Control Board. It seems to me that there ought to be a body of democratically determined law concerning exposure to risks and hazards. Here of course I am talking far outside the nuclear field; I am talking about the entire question of risk analysis and risk assessment.

• 1300

The Atomic Energy Control Board finds itself in the position of making decisions in the public's name. Now, I entirely respect what was in Parliament's mind in giving them that authority. I think another good thing about a democratic system is that you can indeed say to the people who run the hospitals, you are responsible for running the hospitals. But if and when a regulating body, such as AECB has to make up its mind in vacuum about something that is of extraordinarily high public value—what is an acceptable risk—I think they should present that to Parliament and get it endorsed by Parliament. I think the real responsibility lies with the legislators of the world and not with bodies such as AECB.

[*Traduction*]

M. Gagnon: À la page 21 de votre exposé, vous dites que le rapport annuel de la Commission de contrôle de l'énergie atomique devrait être examiné attentivement par le comité parlementaire. Qu'entendez-vous au juste par là?

M. Hare: D'après ce que j'ai pu constater, le comité parlementaire consacre environ deux heures à examiner le rapport de la Commission, alors que cela exigerait au moins deux mois. Votre comité est-il bien chargé de cette inspection? Vous m'excuserez si ce que je dis semble malpoli, madame la présidente.

La présidente: Non, mais votre remarque n'en est pas moins intéressante.

M. Hare: J'estime en effet que le rapport de la Commission est essentiel pour continuer à assurer la sécurité et que la Commission devrait donc avoir recours à un consultant venu de l'extérieur ne faisant pas partie de la Commission ni même de l'énergie nucléaire canadienne en général. En outre les représentants de la Commission devraient justifier leurs décisions. Ainsi le rôle du Parlement serait renforcé.

Je suis d'avis en outre que le Parlement doit absolument suivre de très près le fonctionnement de diverses commissions oeuvrant dans le domaine de l'environnement; en outre il appartient au Parlement de leur fixer les directives à suivre.

Ainsi peu de temps après sa constitution, la Commission de contrôle de l'énergie atomique a décidé que le réacteur nucléaire canadien ne devait pas présenter de risques supérieurs à 1 pour 100,000 ou 1 pour 10 millions de cas. Or à mon avis, une décision de ce genre aurait dû être prise par le Parlement et non pas par la Commission de contrôle de l'énergie atomique. C'est en effet aux représentants du peuple de décider quels sont les dangers que nous devons accepter, et ces décisions devraient à mon avis être consignées dans des lois. Ceci est vrai d'ailleurs non pas uniquement de l'énergie nucléaire mais de tout danger quel qu'il soit.

La Commission de contrôle de l'énergie atomique a la responsabilité de prendre des décisions au nom de la population. Je tiens à dire que j'ai le plus grand respect pour l'intention du Parlement qui lui a donné ce pouvoir. Un des éléments positifs du régime démocratique est que l'on peut dire aux autorités hospitalières qu'elles sont effectivement responsables de l'administration des hôpitaux. Toutefois, quand il s'agit d'un organisme de réglementation comme la Commission de contrôle de l'énergie atomique, qui doit seule se prononcer sur une chose de la plus haute importance pour le public, c'est-à-dire déterminer ce qui constitue un risque acceptable, je pense qu'il doit saisir le Parlement de la question, lequel doit se prononcer. La véritable

[*Text*]

Mr. Gagnon: It is an interesting suggestion. Have the parliamentarians the capability to do that sort of thing? Knowing my colleagues and what is involved in risk analysis, I am not sure we have that sort of a talent.

Dr. Hare: I do not think any group of men and women who are not exposed to the evidence have that talent, but I would say that this committee, for example, would be in an excellent position to quiz the AECB men and women on why they applied these particular standards. What was the sanction? What was the logical argument behind accepting risks on this scale as being of no consequence to the public?

As it is, the board, if it decides to change these things, does so quietly. I am not even sure they ever tell this committee or Parliament. It seems to me to be an anomaly that the level of risk in society should be determined by non-legislative bodies.

The Chairman: To take that further, Dr. Hare, if AECB appeared before this committee and we did question them on why they applied certain standards, do we have the resources or the knowledge amongst us to say that is right, that is wrong? So we are back to your question: Is this the right place to make a judgment?

Dr. Hare: Well, Madam Chairman, what you are on to here is an absolutely central question in the whole area of environment and public health because the same questions come up every time in relation to disease control, the protection of the public against epidemics—things of this sort. All I am really saying is that I believe Parliament needs to be able to challenge the assumptions made by the people who run the hospitals and the people who run the nuclear industry.

If the public thinks the board is taking the wrong standards, then the public spokesman, which is Parliament, should challenge the board about that. That is why I say, it is more like two months than two hours. I think this committee should go through the fine texture of that report and if it discovers assumptions about risk that strike you, as citizens, as being wrong, they should be challenged, and the board should be instructed to alter them and the board would welcome this.

I have been involved in this for the last 40 years. I think at all times the people with whom I have worked in the technical community feel the vacuum in which they are called upon to make judgments concerned with public safety. They are technically competent to make these judgments, but the final question, whether or not the risk is acceptable, is not a scientific or technical question at all. It is a public judgment.

The Chairman: In February, two years ago, under parliamentary reform, standing committees such as this certainly were enabled to hire consultants. We have Mr.

[*Translation*]

responsabilité incombe aux législateurs de ce monde et non à des organismes comme la CCEA.

M. Gagnon: L'idée est intéressante. Les parlementaires ont-ils la compétence nécessaire pour se prononcer? Je connais mes collègues et je sais ce que signifie l'analyse des risques. Je ne suis pas sûr que nous ayons ce qu'il faut pour nous prononcer.

M. Hare: Personne, en l'absence des preuves nécessaires, n'a cette compétence, mais le comité, par exemple, est dans une position avantageuse pour poser des questions à la CCEA sur les raisons qui la poussent à appliquer ces normes-là. Quelle était la sanction? Quel était l'argument logique qui sous-tendait l'acceptation de risques de cet ordre et la conclusion qu'ils ne tireraient pas à conséquence pour le public?

Pour l'instant, la Commission, si elle décide de modifier quelque chose, le fait tout doucement. Je ne suis pas sûr qu'elle le signale ni au comité ni au Parlement. Il me semble qu'il est singulier que le niveau de risque pour la société soit évalué par des organismes non législatifs.

La présidente: Monsieur Hare, si les représentants de la CCEA comparaissaient devant le comité, et si on leur posait des questions concernant le pourquoi des normes appliquées, pensez-vous que nous aurions parmi nous les compétences nécessaires pour faire une évaluation valable? J'en reviens à votre question. Est-ce bien ici qu'il faut porter un jugement?

M. Hare: Madame la présidente, vous venez d'aborder ici une question tout à fait capitale dans le domaine de l'environnement et de la santé publique car elle revient sans cesse pour tout ce qui touche la protection du public contre les maladies et les épidémies, etc. Voici où je veux en venir: le Parlement doit pouvoir contester les hypothèses élaborées par les administrateurs des hôpitaux comme par les responsables du secteur nucléaire.

Si le public est d'avis que la commission a recours à des normes qui ne sont pas valables, le porte-parole du public, qui est le Parlement, devrait pouvoir contester cela. Voilà pourquoi il faut deux mois plutôt que deux heures. Le comité devrait passer ce rapport au peigne fin et s'il estimait que certaines hypothèses concernant les risques ne sont pas valables, il devrait pouvoir les contester et la commission devrait recevoir la consigne de les modifier, et je pense qu'elle accueillerait de bonne grâce ces directives.

Je m'occupe de ce domaine depuis 40 ans. De tout temps, les responsables techniques se sont plaints de l'isolement dans lequel ils sont appelés à porter des jugements concernant la sécurité du public. Ils ont la compétence technique nécessaire pour porter des jugements mais, en dernier ressort, la détermination d'un risque acceptable, n'est pas une question scientifique ou technique. C'est le public qui devrait en décider.

La présidente: En février, il y a maintenant deux ans, la réforme parlementaire a commencé à permettre aux comités permanents comme le nôtre de faire appel à des

[*Texte*]

Clay and Mr. Harris with us today. You have obviously thrown a challenge at us and perhaps one that we will take a long look at.

Dr. Hare: You asked for comment, Madam. I did not throw a challenge. I will never challenge anybody.

The Chairman: We had AECB before us and Dr. Lévesque in his statement or during questioning, stated that he needed 50% more revenues or that his budget should be increased by 50%. Does that sound fair to you?

• 1305

Dr. Hare: It is obviously in the right ballpark, and let me say why. I have so far only mentioned the size of the board. I want the board enlarged because I think it needs to take in the skills that are not there at the present time. But in addition, I think the staff needs to be enlarged in these same areas. They need to have better professional support in the environmental, radiological and socio-economic areas for two main reasons.

One is that I believe the audit of the utilities should be more tightly conducted. Their audit function does not exactly go by the board, but it is not as tight as it would be in other countries because of manpower shortages. That is one point.

Second, I believe the public is unaware—I hope this committee is aware—of the fact that the board has expert committees: an advisory committee on nuclear safety, an advisory committee on radiological hazard. These two advisory committees are first-rate bodies, independent, very well chaired, and have done some good work. They are even less well known than their parent. Nobody has ever heard of them.

If this were the United States, each of those committees would stand almost as independent commissions. Each would have a professional staff. In France they would have a château in which they could do their work. In Britain they would be allowed chocolate biscuits rather than plain cookies. Distinctions would be made. But the important thing is that they would have resources. Even though neither of these committees has complained about this, I think it is absurd that they are not properly staffed. One part-time member of the board staff is at their disposal, and that is it. That is the back-up.

The absolutely crucial role in maintaining public safety is the scrutinizing work of these two committees of the board; yet essentially they are people who can afford to meet twice a year or three times a year with one staff person present, a secretary. Madam, that is just absurd as a device aiming at public review.

[*Traduction*]

experts-conseils. MM. Clay et Harris sont avec nous aujourd'hui. Vous venez de nous lancer un défi manifestement et nous allons certainement y réfléchir sérieusement.

M. Hare: Madame, vous m'avez demandé mon avis. Je ne vous ai pas lancé de défi. Je ne lancerais jamais de défi à qui que ce soit.

La présidente: Les représentants de la CCEA ont comparu et M. Lévesque a dit dans son exposé et en réponse à des questions qu'il fallait que ses recettes soient supérieures de 50 p. 100, c'est-à-dire que son budget soit augmenté de 50 p. 100. Cela vous semble-t-il justifié?

M. Hare: Manifestement, l'ordre de grandeur est juste et je vais vous expliquer pourquoi. Jusqu'à présent, je n'ai parlé que du nombre des commissaires. Il faudrait davantage de commissaires car la commission devrait s'adjoindre des compétences qu'elle n'a pas pour l'instant. En outre, il faudrait que les effectifs soient grossis dans ces domaines-là aussi. Il faut un soutien professionnel accru dans le domaine de l'environnement, de la radiologie, et dans le domaine socioéconomique et ce, pour deux raisons essentiellement.

Tout d'abord, les compagnies de services devraient subir des vérifications beaucoup plus poussées. Les vérifications ne sont pas tout à fait escamotées mais elles ne sont pas aussi serrées que dans d'autres pays étant donné que nous manquons de personnel. C'est une chose.

Deuxièmement—même si le public n'est pas au courant, j'espère que le comité l'est—la commission comporte des comités d'experts: un comité consultatif sur la sécurité nucléaire, un comité consultatif sur les dangers des radiations. Ces deux comités consultatifs sont de premier ordre, indépendants, très bien présidés, et on fait du très bon travail dans certains cas. Ils sont encore moins connus que l'organisme dont ils dépendent. Personne n'a entendu parler d'eux.

Si nous étions aux États-Unis, chacun de ces comités constituerait à lui seul une commission indépendante. Chacun pourrait disposer d'un effectif formé de professionnels. En France, ils disposeraient d'un château pour faire leur travail. En Grande-Bretagne, ils auraient droit à des biscuits au chocolat plutôt que des biscuits secs. On accorderait des distinctions. L'important, c'est qu'ils pourraient compter sur des ressources. Même si ces deux comités ne se sont pas plaints de cette situation, il est absurde de ne pas leur donner l'effectif nécessaire. Un membre à temps partiel du personnel de la commission est à leur disposition, rien de plus. Voilà sur quoi ils peuvent compter.

Le rôle qui est absolument crucial, celui du maintien de la sécurité du public comporte un travail d'analyse que doivent faire ces deux comités de la commission. Pourtant, il s'agit de gens qui ne peuvent se permettre que des rencontres deux fois ou trois fois par année, avec la présence d'un seul représentant du personnel de la

[*Text*]

[*Translation*]

commission, un secrétaire. Madame, c'est tout simplement absurde pour un mécanisme qui a soi-disant la responsabilité d'une révision publique.

The Chairman: I think we totally agree upon that.

Mr. MacLellan: I wonder, Dr. Hare, if you would address the question of the public liability and the sufficiency of $75 million for reactors, actually, in the case of Canada. Compared with other countries that operate nuclear operations, it would be just tokenism as far as public liability is concerned.

Dr. Hare: I think the public liability is effectively unlimited in this area, and no government could afford any other situation. The point is that it is the suppliers of Ontario Hydro and AECL who are effectively covered, I suspect, by the Nuclear Liability Act. Nobody pretends that if Hydro were to do a great deal of damage in the Toronto district the Province of Ontario and the Government of Canada would not have to pay for most of it. They obviously would.

But I think the Nuclear Liability Act was enacted in the first place to provide quick access to compensation for anyone who might suffer. It has been widely interpreted by the critics of the industry in the reverse, that it is a protection for the suppliers. If they do not have to worry about anything beyond $75 million worth of insurance, they are home and dry.

I think the figure of $75 million certainly does require re-examination. However, I am cautious about saying the act ought to be repealed or set on one side. I think there are good arguments behind this and I am not enough of an insurance specialist or lawyer to be wise about it. We got an awful lot of conflicting evidence about this, madam, from the lawyers on the one hand and from activist groups such as Energy Probe on the other. I did not really completely believe anything I heard about it. I think it is something that needs re-examination, and by somebody much more skillful than I am.

La présidente: Je pense que nous sommes tout à fait d'accord là-dessus.

M. MacLellan: Monsieur Hare, pourriez-vous me dire ce que vous pensez de la responsabilité publique et si vous estimez que 75 millions de dollars pour les réacteurs suffisent, au Canada actuellement. Si l'on compare cela à ce qui se fait dans d'autres pays où il y a un secteur nucléaire, c'est une somme purement symbolique qui est consacrée ici à la responsabilité publique.

M. Hare: Je pense effectivement que la responsabilité publique dans ce domaine est illimitée et qu'aucun gouvernement ne peut l'éviter. Toutefois, je pense que ce sont ceux qui approvisionnent l'Hydro-Ontario et l'Énergie atomique du Canada Ltée qui sont visés, de fait, par les dispositions de la Loi sur la responsabilité nucléaire. Personne ne prétend que si l'Hydro causait de gros dommages dans la région de Toronto, la province de l'Ontario et le gouvernement du Canada pourraient éviter d'en faire les frais. Manifestement, la responsabilité leur incomberait.

Je pense toutefois que la Loi sur la responsabilité nucléaire a été adoptée avant tout pour permettre d'accorder un dédommagement rapidement à quiconque serait lésé. Les critiques de l'industrie ont généralement adopté une interprétation contraire, c'est-à-dire qu'ils prétendent que les dispositions de la loi protègent les fournisseurs. Si la responsabilité de ces derniers ne dépasse pas 75 millions de dollars d'assurance, ils s'en tirent indemmes.

Je pense qu'il faudrait revoir ce chiffre de 75 millions de dollars. Toutefois, je n'irais pas jusqu'à dire qu'il faille abroger la loi ou cesser de l'appliquer. Je pense qu'il y a de bons arguments qui militent en faveur de la loi mais je n'ai pas assez de connaissances en matière d'assurance et je ne suis pas avocat, si bien que je ne peux pas me prononcer fermement. Nous avons reçu des témoignages contradictoires de la part d'avocats d'une part et de groupes d'activistes comme les représentants de l'Enquête Énergie, d'autre part. Je n'ai jamais vraiment cru sur parole tout ce que j'ai entendu. Je pense que toute la question mérite d'être revue et qu'il faut laisser cela à des gens beaucoup plus compétents que moi.

• 1310

Mr. MacLellan: Thank you.

The Chairman: That is interesting.

Mr. Gagnon: I wonder if we could just follow through your report. I have some questions in different spots, and we could take them as they come along.

One of your first major recommendations was the human element, and I guess we have already discussed that and how to update it. But you also say "A program is needed from initiation to decommissioning." This is from

M. MacLellan: Merci.

La présidente: C'est intéressant.

M. Gagnon: Je vais me reporter à votre document. J'ai diverses questions à vous poser si bien que je vais le parcourir.

Une de vos principales recommandations vise l'élément humain, et nous avons déjà parlé de cet aspect-là et du moyen d'améliorer les choses. Vous dites également «il faut un programme à partir du lancement

[*Texte*]

page 5, C.R.2.4. Do you feel we do not have a program in place for decommissioning?

Dr. Hare: We do have decommissioning in progress. Ontario Hydro is decommissioning NPD, and AECL is decommissioning Douglas Point at the present time. I did not intend the stress to be on the decommissioning thing. There is no question about it; we have to have a recognized procedure for decommissioning. We have to have it costed and the costs built into the original capital logic of the project, and so on.

What I was really getting at in here is that the very centre of the whole system of industrial control in this business is quality assurance and quality control, as the engineer uses those terms technically. That is just as important at the decommissioning end as it is as you initiate it, and it is also necessary—although it sounds a bit like George Orwell to say this—that the words be taken to apply to human effort as well as materials. In other words, when you talk about quality assurance, you have to make sure the quality of the work done and the way in which the work is done by people is covered, as well as the materials with which they are working.

I should perhaps remind you who my industrial consultants were. The leader of the team was Bill Kehoe, who comes from the oil industry. He ran the Esso resources refineries throughout the country. He was Director of Supply for the Exxon Corporation in all of North America, so he knows a lot about refining. I picked him because refining is an industry which has many of the same characteristics as reactor operation. What struck Bill and his large team of consultants was that although Hydro was fully aware of the importance of quality assurance, they did not see it as a unified system extending right through. They thought of it as a series of detached bodies of method. I was very surprised by this.

They have a great big volume called *The Quality Engineeering Volume*, which is a manual bigger than any of these. This specifies precisely which ASNE standard will apply to which material, and when that shall be checked and by what means it shall be checked. Everything in the engineering side of the operation is absolutely spelled out. But when it came to human performance, although some parts of the quality assurance program do have to do with human performance, nowhere was it spelled out as a consecutive system, largely I suspect because of difficulties between the company and the union.

My consultants felt—and I had to agree with them—that it would pay Hydro to standardize this to make it clear that there was a unified philosophy behind the QAQC process throughout the operation, in human resoures as well as in materials.

[*Traduction*]

jusqu'à la mise hors service». Je tire cela de la page 5, paragraphe C.R.2.4. Avez-vous l'impression qu'il n'existe pas de programme pour la mise hors service?

M. Hare: On procède actuellement à des mises hors service. L'Hydro-Ontario est en train de démanteler la centrale expérimentale d'énergie atomique et l'Énergie atomique du Canada Limitée est en train de démanteler Douglas Point. Je ne voulais pas mettre l'accent sur le démantèlement. Il est indéniable toutefois qu'il faut reconnaître le besoin d'une procédure de mise hors service. Il faut en évaluer le coût et l'intégrer à l'immobilisation de départ de chaque projet.

Ce qui m'intéresse avant tout ici, ce qui est au coeur de tout régime de contrôle industriel dans ce secteur, c'est l'assurance et le contrôle de la qualité, au sens où les ingénieurs utilisent ce terme tehniquement. Ces aspects sont tout aussi importants au moment de la mise hors service qu'au point de départ, et bien qu'on risque de ressembler à George Orwell en disant cela, il est aussi essentiel que ces termes s'appliquent à l'effort humain qu'aux installations. En d'autres termes, quand on parle d'assurance de la qualité, on doit s'assurer que la qualité du travail réalisé et la manière dont ce travail est fait, sont controlées, comme les matériaux dont ils se servent.

Il me faudrait peut-être vous rappeler qui étaient mes experts-conseils industriels. Le chef de l'équipe était Bill Kehoe, qui vient du secteur pétrolier. Il a dirigé les raffineries d'Esso un peu partout au Canada. Il a été directeur de l'approvisionnement à la Société Exxon pour toute l'Amérique du Nord, et il connaît très bien le raffinage. Je l'ai choisi parce que le secteur du raffinage présente beaucoup des mêmes caractéristiques que l'exploitation d'un réacteur. Ce qui l'a frappé, lui et sa nombreuse équipe d'experts-conseils, c'est que même si l'Hydro-Ontario était tout à fait consciente de l'importance de l'assurance de la qualité, elle ne voyait toutefois pas l'uniformité de cet aspect-là dans tout le processus. On semblait croire qu'il s'agissait d'une série de méthodologies distinctes. J'ai été très étonné.

L'Hydro-Ontario a un manuel énorme intitulé *Le manuel de l'ingénierie de qualité*, qui est plus gros que tous ceux-ci. Dans ce manuel figure quelle norme américaine s'appliquera à chaque matériau et quand et comment cela doit être vérifié. Tout ce qui concerne l'ingénierie est précisé dans le moindre détail. Même si certains aspects du programme d'assurance de la qualité visent le côté humain, on ne trouve rien dans ce manuel qui donne les détails d'un régime cohérent, et je suppose que c'est essentiellement à cause de différends entre la société et le syndicat.

Mes experts-conseils, avec lesquels je suis d'accord, estiment que l'Hydro trouverait rentable de normaliser cet aspect-là pour qu'il soit bien clair qu'il y a un régime unique qui sous-tend la procédure de contrôle de la qualité et d'assurance de la qualité, pendant toute l'exploitation, pour l'aspect humain tout autant que le matériel.

[*Text*]

Mr. Gagnon: The next major recommendation was the pressure tube situation, and you talk about the $42 million for R and D. Do you feel this should be done by Ontario Hydro or by AECL?

Dr. Hare: I think it has to be done where the material resources are. It has to be done mainly by AECL, but not necessarily paid for by AECL because it has to be done at Chalk River, which they control, and secondarily at Whiteshell. Only to a minor extent is the work done in Hydro labs or in Westinghouse, which are the only places in this country where it can be done.

• 1315

What I feel is that the $19 million committed from Ontario Hydro's budget is very small in relation to the scale of the problem. I expected them to pay virtually the whole of that $42 million, which in any case is small in relation to the size of the problem.

So that is the reason behind those paragraphs: surprise that Hydro was apparently getting away with paying so small a part of what is already an inadequate provision.

Mr. Gagnon: I take it you feel the final solution for the pressure tubes is somewhere off in the future.

Dr. Hare: I think, like every other real-world problem, this is far too complicated for me to answer you in two or three sentences. But since you raise the matter, I will try.

First of all, I would put very high on my list of necessities a better system of in-reactor testing, so at all times you can tell what the condition of each of these tubes is. The development of apparatus to do this is largely done by AECL.

Mr. Gagnon: Are you talking about measuring devices on an operating reactor, on each of the pressure tubes?

Dr. Hare: Yes; that plus remote probes that can be used more efficiently when the reactor is shut down. Remember when you shut a reactor down there is still such a strong gamma-radiation field you cannot go anywhere near it. So you have to have remote-control probing. The development of instruments tough enough to do this and to answer the right questions has largely been undertaken by AECL, but with, obviously, a lot of help from Hydro. I think that has to continue.

The second aspect of this work is the solution of fundamental metallurgical questions: why do hydrides form in these metals? Why do they migrate to certain weakness points? Is a better alloy possible? Can we find a

[*Translation*]

M. Gagnon: L'autre recommandation importante concerne les tubes de force, et vous parlez de 42 millions de dollars qu'on investirait dans la recherche et le développement. Est-ce que vous pensez que ce devrait être fait par l'Hydro-Ontario ou par l'Énergie atomique du Canada Limitée?

M. Hare: Je pense que cela devrait être fait là où se trouve la ressource. Essentiellement, ce devrait être l'EACL, qui n'en paierait pas nécessairement la facture, mais ce devrait être fait a Chalk River, que l'EACL contrôle, et ensuite à Whiteshell. Un travail mineur devrait être fait dans les laboratoires de l'Hydro ou à Westinghouse, qui sont les seuls endroits au Canada où cela peut être fait.

J'estime que les 19 millions de dollars prévus dans le budget d'Hydro-Ontario sont très légers compte tenu de l'importance du problème. Je m'attendais à ce qu'ils assument pratiquement la totalité de ces 42 millions de dollars qui de toute façon ne représentent pas grand-chose compte tenu de l'ampleur du problème.

C'est ce qui explique ces paragraphes: notre surprise qu'Hydro s'en tire apparemment en ne versant qu'une si petite partie de ce qui au départ était déjà insuffisant.

M. Gagnon: J'en conclus que pour vous la solution définitive au problème de ces tubes de force n'est pas pour demain.

M. Hare: Comme pour tous les autres problèmes d'ordre pratique, celui-ci est beaucoup trop compliqué pour que je puisse vous répondre en deux ou trois phrases. Mais puisque vous m'avez posé la question, je vais essayer.

Pour commencer, tout en haut de ma liste des nécessités je mettrais un meilleur système de contrôle à l'intérieur du réacteur afin qu'à tout moment on puisse constater l'état de chacun de ces tubes. L'EACL est un des pionniers dans la conception de ces appareils.

M. Gagnon: Est-ce que vous voulez parler d'appareils de mesure fixés sur chacun des tubes de force d'un réacteur en service?

M. Hare: Oui; plus des sondes télécommandées qui peuvent être utilisées de manière plus efficace quand le réacteur est hors service. N'oubliez pas que lorsqu'on arrête un réacteur le champ de rayons gamma qu'il émet reste si fort qu'il est impossible d'en approcher. Ces mesures de contrôle ne peuvent être faites qu'à distance, par télécommande. La mise au point d'appareils suffisamment résistants pour faire ce travail et répondre aux bonnes questions est effectuée en grande partie par l'EACL mais, avec, de toute évidence, une aide importante d'Hydro. Il faut que cela continue.

Le second aspect de ce travail est la résolution de questions métallurgiques fondamentales: pourquoi des hydrures se forment-ils dans ces métaux? Pourquoi se fixent-ils sur certains points de faiblesse? Un meilleur

[*Texte*]

better alloy? What system of testing before you put it into the reactor and after it is in the reactor will give you the fastest answer to whether you are on the right track or not? Really, there is no proof of this pudding other than actually eating it. In other words, you have to put them into the reactor and see how they work.

Mr. Gagnon: For years.

Dr. Hare: Yes, for years. That is why I say there is no short-term solution to this question.

What I felt was that the scale of work undertaken seemed very small. When I asked a whole group of people, friends in other industries, off the tops of their heads, if they had revenues of $2.5 billion per year that were crucially dependent on the integrity of the technology, what would they spend on any defect that developed in that technology, nobody thought 2% was a high enough figure. Absolutely nobody. And that is what this is.

Mr. MacLellan: Do we really know how much it is going to cost to correct the pressure tube problem?

Dr. Hare: The costs are primarily the fact that you have to take the reactor out of production. You therefore lose the revenues from the electric production. It cost about $425 million in two years to take Pickering "A1" and "A2" out of production and replace the pressure tubes. It is of that order of magnitude. When you shut a reactor down, it will be out of service for a couple of years for this purpose. You will lose some hundreds of millions of dollars worth of production. The rest of the cost, though not negligible, is still manageable. The real cost is that you have to shut the damn things down.

Of course, they assumed when they built them that would have to be done every 25 or 30 years. Indeed, they did more than that. In estimating the capital cost of these things I think they assumed only a 15-year life. But it is now beginning to look, or it has looked for some time, as if a much shorter turn-around time will become standard. That, of course, adds to the capital cost of the project; and it is a very large capital cost.

However, I have just come from a meeting of the Canadian Nuclear Association, where I was defending myself before them. I did hear it said there that with the experience they have had at Pickering it does now look as if they can pretty much rely on 10 to 15 years at least of operation from their improved tubes, especially with the sensors that I talk about.

• 1320

A last point. You will notice the word "metallurgical" here. The story of these alloys and of our capacity to produce these alloys is itself a fascinating story. The zirconium alloys that we use, which are the only ones we

[*Traduction*]

alliage est-il possible? Peut-on trouver un meilleur alliage? Quel système de contrôle une fois installé dans le réacteur vous permettra de déterminer le plus vite si vous vous êtes trompés ou non? À vrai dire, le seul moyen c'est d'essayer. Autrement dit, il faut installer ces systèmes dans le réacteur et mesurer leur comportement.

M. Gagnon: Pendant des années.

M. Hare: Oui, pendant des années. C'est la raison pour laquelle je dis qu'il n'y a pas de solution à court terme à cette question.

C'est pourquoi j'ai pensé que ces travaux me semblaient être menés sur une bien trop petite échelle. Quand j'ai demandé à brûle-pourpoint à tout un groupe de personnes, à des amis dans d'autres industries: si vous aviez des recettes de 2,5 milliards de dollars par an dépendant d'une manière cruciale de l'intégrité de la technologie, quelle portion en consacreriez-vous à tout défaut détecté dans la cuirasse de cette technologie? Personne ne m'a répondu penser que 2 p. 100 était suffisant. Absolument personne. Et pourtant c'est ce qui se passe ici.

M. MacLellan: Savons-nous vraiment combien coûtera la résolution des problèmes des tubes de force?

M. Hare: Le coût avant tout est causé par le fait que le réacteur doit être mis hors service. La conséquence est une perte de recettes de production électrique. Il a fallu mettre hors de service pendant deux ans les réacteurs «A1» et «A2» de Pickering pour remplacer les tubes de force et la note a été d'environ 425 millions de dollars. C'est de cet ordre. Quand on arrête un réacteur, pour cette opération, il faut compter sur une mise hors service pendant deux ans. La perte de production représente plusieurs centaines de millions de dollars. Le reste du coût, sans être négligeable, est abordable. Ce qui coûte le plus cher c'est qu'il faut mettre hors service ces satanés trucs.

Bien entendu, ils ont supposé quand ils les ont construits qu'il faudrait le faire tous les 25 ou 30 ans. En fait, ils ont fait plus que cela. Dans le calcul des coûts ils ont fixé le cycle de vie à 15 ans. Il semblerait maintenant, ou plutôt il semble déjà depuis un certain temps, qu'un cycle beaucoup plus court deviendra la norme. Bien entendu, cela augmente d'autant le coût qui est déjà très important.

Cependant, je reviens d'une réunion de l'Association nucléaire canadienne où j'ai dû défendre mes arguments. Je les ai entendus dire que forts de leur expérience de Pickering ils estiment désormais pouvoir compter sur un minimum de 10 ou 15 ans de fonctionnement de leurs tubes améliorés surtout avec les détecteurs dont j'ai parlé.

Un dernier point. Vous aurez remarqué la présence de l'adjectif «métallurgique». L'histoire de ces alliages et de notre capacité à les produire est en elle-même une histoire fascinante. Les alliages au zirconium que nous

[*Text*]

know about at the moment that are suitable for use to emit the required neutron flux, were actually put onto the market by Chinese entrepreneurs operating in Oregon, a company called Wah Chang. They are now Teledyne-owned, but there is only one producer and this is at Waterville, Oregon.

By absolute chance—I was the president of Sigma Xi, the American scientific research society—I went to a chapter meeting because my daughter teaches at Oregon State and they invited me to go there. I wanted to see my daughter, instead of which I found myself sitting next to the president of Wah Chang. He said, "Do you realize that we produce these alloys for you?" I said, "I am afraid I did not".

We do not have the capacity in this country really to produce such alloys, nor do we have the capacity to experiment, to look for better alloys. Much of the initiative is being done by the Soviet Union. This is a real hole, a real vacuum. Bill Morrison is very fond of saying it is all very well for you to say we do not spend enough on research but we cannot find the people to spend the research on, nor can we find the labs in which to do the research. There is a vacuum here, in other words, in which the Canadian industry and the Canadian universities fall a long way short in what really is needed to give us full, sort of technical autonomy.

Mr. Gagnon: If I could follow up on that. The supplement to *The Financial Post* dated June 13 shows the front sort of face of the tubes, 480 of them. There is no doubt that the plumbing is awfully, awfully complicated compared with anybody else. And then you look at what the rest of the world has. We have 60% pressurized water systems that we are currently operating and of what is being built, three-quarters are pressurized water. Everybody else has gone down the road of heavy water—Sweden, for instance—and they have all backed off. Have we made a mistake, historically holding onto heavy water? Or do we have something unique that the rest of the world does not have that is beneficial to Canada? How do you assess that aspect?

Dr. Hare: At the moment the CANDU looks remarkably good. It is true it is expensive and the expense arises quite largely from two things: first of all, the complexity of the plumbing that you have already mentioned, and second, it arises from the fact that our reactors require a higher degree of precise monitoring. We have to have fast shutdown systems in our reactors because they have a positive void reactivity coefficient, and that means our reactors are a mass of control systems. It is not only that they are complex from a plumbing standpoint; they are also complex from an electrical control point of view. That alone makes them very expensive.

[*Translation*]

utilisons, alliages qui sont les seuls pour le moment, à notre connaissance, capables d'émettre le flux de neutrons nécessaires, ont été mis sur le marché par des entrepreneurs chinois de l'Oregon, la compagnie Wah Chang. Ils ont été rachetés par Teledyne, mais il n'y a qu'un seul producteur et c'est à Waterville en Oregon.

Par le plus grand des hazards—j'étais président de Sigma Xi, la société américaine de recherche scientifique—je m'étais rendu à une réunion de chapitre parce que ma fille enseigne à l'université de l'Oregon et ils m'avaient invité à venir. Je voulais voir ma fille mais à la place je me suis retrouvé assis à côté du président de Wah Chang. Il m'a dit: «Savez-vous que nous fabriquons ces alliages pour vous?» Je lui ai répondu: «Je regrette, non».

Nous n'avons pas vraiment tout ce qu'il faut chez nous pour fabriquer de tels alliages pas plus que nous n'avons ce qu'il faut pour faire des expériences, trouver de meilleurs alliages. Les Soviétiques sont à l'avant-garde dans ce domaine. Chez nous, c'est le vide sidéral. Bill Morrisson aime beaucoup répéter qu'il est très facile de dire que nous ne consacrons pas suffisamment d'argent à la recherche mais il est impossible de trouver les spécialistes à qui confier ces recherches et tout aussi impossible de trouver les laboratoires où les mener. Il y a donc un vide, en d'autres termes, qui tant qu'il ne sera pas comblé par l'industrie canadienne et les universités canadiennes nous empêchera d'être techniquement autonomes.

M. Gagnon: Permettez-moi de continuer. Le supplément du *Financial Post* daté du 13 juin montre une vue de face de ces tubes, 480 en tout. Il est incontestable que comparer à ce qu'utilisent les autres cette plomberie est horriblement compliquée. Il suffit de regarder ce qui se fait dans le reste du monde. Soixante p. 100 de nos centrales en service sont à eau pressurisée et les trois quarts de celles qui sont en construction sont à eau pressurisée. Tous ceux qui avaient opté pour la filière de l'eau lourde—la Suède, par exemple—y ont depuis renoncé. Avons-nous fait une erreur historique en nous cramponnant à la filière de l'eau lourde? Ou avons-nous quelque chose d'unique que le reste du monde n'a pas et qui est bénéfique pour le Canada? Quelle est votre position?

M. Hare: Pour le moment le CANDU se comporte remarquablement bien. Il est vrai qu'il est cher et que deux choses en particulier en sont responsables: premièrement, la complexité de la plomberie que vous avez déjà mentionnée, et deuxièmement, le fait que nos réacteurs ont besoin d'être surveillés de beaucoup plus près. Il faut que nos réacteurs soient équipés de circuits d'extinction rapide car leur coefficient de vide est positif et cela signifie que nos réacteurs sont une masse de circuits de contrôle. Non seulement ils sont complexes du point de vue de la plomberie mais aussi du point de vue du contrôle électrique. Rien que cela les rend très chers.

[*Texte*]

On the other hand, look at that table which you have in front of you. It is consistently true. The Canadian reactors go on operating. Even allowing for the shutdowns at Pickering and Bruce, pressure tube failures, they outperform their neighbours. And they have a very good neutron economy. So as long they can operate for a couple of decades, three decades, without major defect, and as long as the public is protected, then it may well be that in the beginning of the next century this country will appear to have been the people who made the right bet and everybody else made the wrong bet.

I have put this very question, Madam Chairman, to Walter Marshall, the chairman of the Central Electricity Generating Board. Have you ever had him as a witness?

The Chairman: We did not have Mr. Marshall, no.

• 1325

Dr. Hare: He would be worth bringing in; he is dynamite.

He said: look, you have a good going in Canada; do not louse it up. That was his first advice to me. I said: well, if we have a good thing going in Canada, then why are you not using CANDU reactors, because I know you consider them. His response was quite surprising to me. He said: fundamentally, it is a matter of regulation; we do not dispute the technical competence of the CANDU reactor, but it is very complex and to get it past our nuclear installations inspector would take 10 years of wrangling with our regulating body, and you would not have anybody who could offer us package deals on this.

This is what he is doing of course. If he goes to Westinghouse and says that he wants to put in a PWR reactor, one of theirs, then Westinghouse will provide him not only with the reactor but also with a complete package of the material that NII, their regulating body, need from him to grant a licence.

He says he can get a Seiswel "B" licensed in a third of the time it would take him to get a CANDU licence.

The complexity turns out to be a problem in two ways: (1) the higher capital costs and (2) the regulating problems in dealing with the world's regulators.

I do not think we will ever succeed in getting this kind of reactor past the big countries that have made the step of going the pressurized water route, as the French and the Japanese have.

Mr. Gagnon: To follow up on the uniqueness of the CANDU, on page 9 you talk about the separation of the coolant and the moderator. Is that an advantageous situation?

Dr. Hare: Very much so.

[*Traduction*]

En revanche, si vous consultez le tableau que vous avez devant vous, vous verrez que la supériorité du produit canadien est constante; les réacteurs canadiens, même si on compte les arrêts de Pickering et de Bruce, et les problèmes de tubes de force, sont supérieurs à leurs concurrents. Ils ont aussi une bonne économie de neutrons. Donc, tant que leur cycle de vie est de deux décennies, trois décennies sans problème majeur, et tant que le public est protégé, il se peut fort bien qu'au début du prochain siècle notre pays soit considéré comme celui où le bon choix a été fait alors que tous les autres se sont trompés.

J'ai posé cette même question, madame la présidente, à Walter Marshall, le président de la Central Electricity Generating Board. L'avez-vous jamais eu comme témoin?

La présidente: Non.

M. Hare: Cela vaudrait la peine, c'est de la dynamite.

Il m'a dit: écoutez, vous avez un bon truc qui marche au Canada, ne le sabotez pas. C'est le premier conseil qu'il m'a donné. Je lui ai dit: si nous avons un bon truc au Canada, pourquoi dans ce cas n'utilisez-vous pas de réacteur CANDU—je sais que vous y avez pensé. Sa réponse a été assez surprenante. Il m'a dit: fondamentalement, c'est une question de règlements, nous ne contestons pas la compétence technique du réacteur CANDU, mais il est très complexe et pour le faire accepter par notre inspecteur d'installations nucléaires, il faudrait nous battre pendant dix ans avec notre organisme de réglementation et en plus vous n'aviez personne qui puisse nous offrir un forfait.

Bien entendu, c'est ce qu'il fait. S'il dit à Westinghouse qu'il veut un réacteur à eau pressurisée, un de ses réacteurs, Westinghouse lui livre non seulement le réacteur mais tout ce que la NII, leur organisme de réglementation, réclame pour délivrer un permis.

Selon lui, il lui faut trois fois moins de temps pour obtenir un permis pour un Seiswel «B» que pour un CANDU.

Cette complexité se transforme en problème de toute manière: premièrement le coût plus élevé et deuxièmement les problèmes de réglementation avec les organismes des autres pays.

Je ne crois pas que nous arriverons jamais avec ce réacteur à battre sur leur propre terrain les grands pays qui ont opté pour la filière de l'eau pressurisée, comme la France et le Japon.

M. Gagnon: Toujours au sujet du caractère unique du CANDU, à la page 9 vous parlez de séparation du réfrigérant et du modérateur. Est-ce un avantage?

M. Hare: Très certainement.

[*Text*]

Mr. Gagnon: Why is that?

Dr. Hare: On several grounds.

This, incidentally, was part of the reason why Chernobyl caused as much trouble as it did; they do not have that separation.

First of all, you can keep the moderator cool, at 70° Celsius, whereas the coolant is hot, 320°—that sort of thing. If there is a break in the primary heat transport system, a LOCA, which everybody fears in this industry, then the problem in the first two or three seconds is to get rid of the heat, and that cool moderator can serve as an initial heat sump. So you have a stabilizing thing tending to stabilize temperature, and the fact that the moderator will keep circulating and is cool is part of the reason.

The other part of the argument is this. If you do not have a separation of moderator from the coolant and you have a breach in the thing, then the volume of water available to flash into steam is very much greater. The amount of steam that can actually flash in a CANDU if there is a LOCA is restricted by the fact that the heat transport system has a comparatively low volume.

Those are the two reasons why.

Mr. Gagnon: You also mentioned the positive void reactivity coefficient. Would you explain what that is please, and why it is detrimental?

The Chairman: What page was that on?

Mr. Gagnon: Page 9, last sentence.

Dr. Hare: What engineers mean by voids is not emptiness but steam, in this context. Inside the cooling system of a CANDU reactor, the heavy water is under extreme pressure, 18 megapascals—or is it 12 megapascals? It is a lot of pressure. I have forgotten exactly what the value is.

What you have, then, is compressed heavy water at a high temperature, 320° Celsius. If there is any significant break in the boundary of that high-pressure system and the pressure falls, then the water instantly boils, meaning that it turns itself into bubbles, or voids.

These voids are very different in relationship to the flux of neutrons, and the flux of neutrons is greatly increased as soon as the voids appear, which means that the rate of fission in the vicinity of that tube increases in the reactor, and that produces an explosive take-off.

• 1330

In the main report—which I think I am going to leave with the committee, if the committee can stand it, Madam Chairman—you will find a diagram showing that within 2.2 seconds, because of that positive void coefficient after the initial break, you have an explosive build-up of

[*Translation*]

M. Gagnon: Pourquoi?

M. Hare: Pour plusieurs raisons.

Incidemment, c'est en partie la raison pour laquelle à Chernobyl il y a eu tant de problèmes, il n'y a pas cette séparation.

Pour commencer, vous pouvez maintenir le modérateur à une faible température, à 70 degré celsius, alors que le fluide de refroidissement est à une température élevée—320 degrés—ce genre de chose. S'il y a une rupture dans le système caloporteur, un accident de perte de réfrigérant primaire, ce que tout le monde craint dans cette industrie, le problème alors dans les deux ou trois premières secondes est de se débarrasser de cette chaleur, et ce modérateur peut être utilisé comme première soupape de chaleur. Vous avez donc un appareil stabilisateur qui tend à stabiliser la température et le fait que le modérateur continue à faire circuler le fluide à basse température est une partie de la raison.

L'autre raison est la suivante. Si le modérateur n'est pas séparé du fluide de refroidissement et qu'il y a une rupture, le volume d'eau se tranformant en vapeur et beaucoup plus élevé. Le volume de vapeur qui se répand dans un CANDU en cas d'accident de perte de réfrigérant primaire est limité par le faible volume comparatif du système caloporteur.

Ce sont les deux raisons.

M. Gagnon: Vous avez aussi parler du coefficient de vide positif. Pourriez-vous également nous expliquer, s'il vous plaît, la raison pour laquelle c'est mauvais?

La présidente: À quelle page?

M. Gagnon: À la page 9, la dernière phrase.

M. Hare: Dans ce contexte par vide les ingénieurs n'entendent pas vacuité mais vapeur. À l'intérieur du circuit de refroidissement d'un réacteur CANDU, l'eau lourde subit une très forte pression, une pression de 18 mégapascals, ou est-ce 12 mégapascals? La pression est très forte. Je ne me souviens plus exactement de sa valeur.

Vous vous retrouvez avec de l'eau lourde comprimée à température élevée, à 320 degrés celsius. S'il y a une rupture importante dans l'enceinte de ce circuit à haute pression et que la pression tombe, l'eau boue instantanément c'est-à-dire qu'elle se transforme en bulles ou en vides.

Ces vides sont très différents par rapport au flux de neutrons et le flux de neutrons est grandement accru dès que ces vides apparaissent ce qui signifie que le taux de fission dans le voisinage de ce tube augmente dans le réacteur et produit un début d'explosion.

Dans le rapport principal, que je suis disposé à vous laisser entre les mains, si vous êtes capable d'en supporter le poids, madame la présidente, vous trouverez un diagramme qui vous montre qu'en l'espace de 2,2 secondes, la fissure initiale ayant fait passé le coefficient

[*Texte*]

pressure in the system because of the increased reactivity. It only takes about 3.7 seconds to burst the calandria as the result of this build-up. That is what I meant by a positive void reactivity coefficient. When the water boils and becomes steam, the reactivity, which means the power output of the reactor, increases explicitly within split seconds. That does not happen in many other reactor designs. In other reactor designs, if the coolant turns into void, you actually lose reactivity and the reactor shuts itself down.

Mr. Porter: You mention on page 12, under risk accidents, that abnormal incidents are common in generating stations, in the order of 700 significant reports a year; that those with significant consequences are examined internally and appropriate measures are taken; and that they are reported to the AECB and the Ontario Legislature.

First of all, what are considered significant consequences? Those reports that are submitted, are they made public; and does the Ontario Legislature publish those reports at a later time? You mention later about the AECB retaining its present power, sanctions, and functions and ensuring that the reasons for its decisions are promptly published and enforced. Is that not happening now?

Dr. Hare: It has not always happened in the past. There are two questions there. Could I take first the one about significant event reports, and then secondly the one about coming clean as to why decisions are taken?

The NCRs are divided up into so-called consequence classes. If an electric light bulb in the antechamber of the control room burns, that is not a significant event report. But if a source of light inside a chamber where a dial has to be read burns, which has some safety signficance, that would be a signficant event report. The fact that it had gone and been changed would be reported. In fact, every maintenance worker and every controller in the whole system maintains a diary of everything he does, and if it is not part of his routine job, if it is not something that happens every Monday, Tuesday, Wednesday, Thursday, as a matter of course, it is noted.

They are then sorted into consequence classes, which are clearly defined by Ontario Hydro, and sent on their way to the Nuclear Interrogatory Review Committee. I am not quite sure who in the system it is who sorts this out, but in the first instance the report is made with the

[*Traduction*]

cavitaire au positif, il se produit une mise en pression explosive dans le système à cause de la réactivité accrue. La mise en pression est telle qu'il suffit d'à peine 3,7 secondes pour faire exploser la calandre. Voilà ce que j'entends par coefficient de réactivité cavitaire positif. Lorsque l'eau bout et s'évapore, la réactivité, c'est-à-dire le rendement de puissance du réacteur, augmente sensiblement en fractions de secondes à peine. Cela ne se produit pas dans la plupart des autres types de réacteurs. Dans ces autres réacteurs, s'il y a perte de fluide de refroidissement, il y a aussi perte de réactivité et le réacteur s'arrête de lui-même.

M. Porter: À la page 12, au chapitre des risques d'accidents, vous dites que les incidents anormaux sont fréquents dans les centrales électriques, de l'ordre de 700 par année; vous dites aussi que les incidents dont les conséquences peuvent être importantes sont étudiés intra-muros et que les mesures appropriées sont prises; on rend ensuite compte de ces incidents à la Commission de contrôle de l'énergie atomique, et au Parlement ontarien.

Tout d'abord, quels sont les incidents que vous considérez comme importants? Les rapports soumis sont-ils rendus publics? Le Parlement ontarien publie-t-il ces rapports ultérieurement? Vous parlez ensuite de l'importance de maintenir les pouvoirs actuels, l'autorisation de sanctionner et les fonctions actuelles de la Commission de contrôle de l'énergie atomique, et l'importance de publier rapidement les raisons pour lesquelles la commission a pris telle ou telle décision et l'importance de les faire appliquer le plus rapidement possible. N'est-ce pas ce qui se fait déjà?

M. Hare: Non, cela n'a pas toujours été le cas. Vous m'avez posé deux questions. Puis-je d'abord répondre à celle qui porte sur le compte rendu des incidents importants, puis je passerai à votre deuxième question et expliquerai pourquoi il est important de bien justifier les décisions.

Les accidents sont divisés en catégories selon l'importance qu'ils peuvent avoir. Par exemple, si une ampoule électrique dans l'anti-chambre de la salle de contrôle grille, cela n'est pas considéré comme un événement d'importance. Mais si la source de lumière à l'intérieur d'une chambre où il faut pouvoir lire un cadran vient à griller, ce qui peut avoir des répercussions importantes pour la sécurité, cela devient par le fait même un événement important qui est signalé dans un rapport. Le fait que l'ampoule ait grillé et qu'elle ait été changée est inscrit dans le rapport. Tous les préposés à l'entretien et tous les contrôleurs, où qu'ils travaillent dans le système, maintiennent un registre de tous leurs gestes, et lorsqu'ils font quelque chose qui n'est pas courant, qui ne se produit pas tous les jours de la semaine, par exemple, ils le notent.

Chaque événement est ensuite réparti en catégories selon son importance, catégories qui sont clairement définies par l'Hydro-Ontario, puis envoyées dans un rapport au Nuclear Interrogatory Review Committee. Je ne sais pas exactement qui fait la répartition des incidents,

[*Text*]

operator's name on it. Some official, and I have to confess I do not know who this is, then rewrites this so as to take the operator's name out of it, and it becomes an anonymous report of an event as distinct from a comment made by an individual. This is to protect the individual, but it is also to encourage the individual to speak freely. The anonymous report then goes up the ladder to Bill Morrison's staff in the Nuclear Interrogatory Review Committee, which sorts out the cases that are of sufficiently high consequence, from the point of view of public safety, to justify discussion by the committee itself.

The committee considers them all and ordains what action has to be taken, and records this fact. You can see all of this in the full annual report of the committee which goes to the Ontario Legislature. It is the most boring reading after the list of "begats" in the Old Testament. But it still can be done.

• 1335

They also go to the Atomic Energy Control Board, who do not, however, publish their audit. They do audit them, but they do not publish the audit. I think they should.

That is roughly it.

What it boils down to is this. Just about everything that happens in the station touching on the operational systems is recorded on paper, and those bits of it that have potential safety consequences flow upwards. Saying there are 700 accidents on the station, which is what anti-nuclear pundits do, is an exaggeration; but there are 700 opportunities for accident, in the sense that some of those might well turn out to be more severe than they at first appear. Things like a broken pressure tube are significant events, just as the failure of a light fixture inside some critical area is a signficant event. So you have to have some kind of sorting system.

I think on the whole it works very well. I am disturbed about the fact that there are differences between stations. With some stations clearly the management requires that many more of these be filed than at others. For example, at Pickering "B" it is about 290 a year, and there is another reactor where it is only about 80 a year; and I cannot believe a brand new station like Pickering "B" requires as many as an old station does. So it seems to me there are differences of culture here that ought to be removed.

[*Translation*]

mais je sais qu'au départ, le rapport est fait au nom de l'opérateur de machine. Ensuite, quelque agent au rang plus élevé, je ne sais pas exactement qui, reprend le rapport pour le réécrire, pour en supprimer le nom de l'opérateur, et pour qu'il devienne un compte rendu anonyme d'un événement plutôt qu'un commentaire individuel. Nous voulons ainsi protéger l'employé qui a signalé l'incident, et l'encourager à s'exprimer librement. Le rapport anonyme suit ensuite la filière et se retrouve au bureau de Bill Morrison du Nuclear Interrogatory Review Committee, là où on fait le tri des incidents qui sont suffisamment graves, du point de vue de la sécurité du public, pour justifier que l'on en discute au comité même.

Ce dernier se penche sur chacun des incidents, et décide quelles mesures doivent être prises, ce dont il prend note. Vous pouvez trouver tous ces renseignements dans le rapport annuel du comité qui parvient au Parlement ontarien. C'est le document le plus ennuyant à lire, après la liste des «descendants» de l'Ancien Testament. Mais on peut toujours le lire si on le veut.

Les rapports sont ensuite envoyés à la Commission de contrôle de l'énergie atomique, qui, pour sa part, ne publie pas son évaluation, à elle. Elle fait sa propre évaluation des rapports, mais n'en publie pas les résultats. Personnellement, je pense qu'elle devrait le faire.

En gros, voilà.

Si je peux me répéter, tout ce qui se passe dans une centrale et qui a rapport avec son système d'exploitation est inscrit dans un registre, et tous les incidents qui pourraient avoir quelques conséquences du point de vue de la sécurité font l'objet d'un compte rendu spécial qui remonte la filière. Les tenants de l'antinucléaire exagèrent lorsqu'ils parlent de 700 accidents dans les centrales; je dirais plutôt qu'il y a 700 risques d'accident parce que certains incidents peuvent fort bien être plus graves qu'ils ne paraissent au début. Une fissure dans un tube de force peut être un événement important, tout comme une ampoule grillée dans une région critique du système. Vous comprenez donc pourquoi il faut avoir un système de tri des événements.

Je trouve qu'en gros, notre façon de faire donne de bons résultats. Ce qui me dérange, c'est qu'il y ait des différences d'une centrale à l'autre dans la façon dont on réagit aux incidents. Dans certaines centrales, la direction exige que l'on fasse un compte rendu d'à peu près tout ce qui survient. Ainsi, à la centrale de Pickering «B», on rencontre environ 290 incidents par année, alors qu'ailleurs le nombre d'incidents atteint à peine les 80 par année; et je ne peux croire qu'il soit nécessaire de faire autant de comptes rendus dans une toute nouvelle centrale comme celle de Pickering «B» que dans des vieilles centrales. Il me semble qu'on devrait abolir ces différences.

[*Texte*]

To come to the board, the way the board operates is by exchange of correspondence between the president and the chairman of Hydro. The board considers matters. What that means is that its staff do a hell of a lot of work. They really do. They work this over. For months there will be an exchange of correspondence, verbal and written, between the staff of AECB and the staff of Hydro. When it finally reaches the point of a board decision, that decision is then written by the staff for discussion by the board. It goes to the board. If the board adopts it, the president of AECB then writes a letter to the chairman of Hydro, saying what the decision is and giving an outline of the reasons. But it takes a great deal of research to find out what really happens in those difficult cases that go wrong.

One of the submissions made to us was that the whole question of the emergency coolant injection system at Bruce "A", which was a *cause célèbre* that went on for about 12 years. . . it was quite impossible to tell from the letters exchanged between the top executives what really happened. Of course it was alleged by the industry's critics that the board was in fact being intimidated by Hydro on this matter.

Well, this is ancient history, and the Ontario select committee on Hydro affairs have already gone into it and published an analysis of it. If you want to look into this in detail, the account given by Energy Probe in their submission to us is essentially correct. It is what happened.

We felt it was absurd that all this work should be done in such a way as to leave the suspicion that the public interest was not being protected. We felt, therefore, that with all decisions of the board, licensing decisions, modification decisions, anything that has a bearing on public safety, the letters of exchange ought to be absolutely explicit and include a complete, detailed statement of the reasons for the decisions and a timetable for their execution. They do not, or they have not done so in the past.

Mr. Gagnon: I am up to where you are talking about loss of regulation. You point out that it has not been analysed. Can you tell us what loss of regulation is and why has it not been analysed?

Dr. Hare: The striking thing about a nuclear reactor is that it is regulated to within an inch of its life. You get the reactor up to criticality and you then hold it there, almost exactly at criticality. It is not somebody holding knobs who does this. It is a control computer, or a bank of control computers, that does it.

• 1340

If for some reason—an explosion in the control room or an earthquake or some external factor—the control computers lose control, that is obviously a major concern because you are taking the controls off a system that has

[*Traduction*]

Revenons à la commission: celle-ci échange de la correspondance avec le président de l'Hydro. Son rôle est d'étudier des questions, c'est-à-dire que son personnel abat un travail énorme et revoit tout cela. Pendant des mois, il y a correspondance ou conversation entre le personnel de la Commission de contrôle et celui de l'Hydro. Lorsqu'enfin la commission est en mesure de rendre un jugement, celui-ci est préparé par le personnel pour que les commissaires puissent en discuter. Si le jugement est entériné par la Commission de contrôle, son président écrit alors au président de l'Hydro pour lui faire part de son jugement et de ses raisons. Mais il faut beaucoup de recherche pour déterminer vraiment ce qui s'est passé dans les cas difficiles où il y a eu des pépins.

Un des dossiers qui nous avaient été transmis concernait le système d'injection du fluide de refroidissement caloporteur à la centrale Bruce «A», qui est à l'origine d'une cause célèbre qui a duré environ 12 ans. . . En fait, il nous avait été quasi impossible de comprendre, à partir des lettres échangées entre les dirigeants, ce qui s'était vraiment passé. Bien sûr, les critiques de l'industrie nuléaire ont prétendu que la commission avait cédé aux intimidations de l'Hydro.

Tout cela est de l'histoire ancienne, et le comité ontarien sur les affaires de l'Hydro s'est déjà penché sur la question et en a publié une analyse. Si vous voulez voir tout cela en détail, je peux vous dire que le rapport transmis par Energy Probe dans son mémoire est essentiellement correct et décrit bien ce qui s'est passé.

Il est absurde que, malgré tout le travail effectué, le public ait encore l'impression que l'on n'a pas protégé ses intérêts. C'est pourquoi nous avons décidé que, contrairement à ce qui s'est fait par le passé, tous les jugements de la commission au sujet de l'octroi de permis et de modifications, autrement dit tout ce qui peut avoir une incidence sur la sécurité du public, les lettres de correspondance, devraient être absolument explicites et inclure un exposé détaillé des raisons avancées ainsi qu'un canlendrier de mise en vigueur des mesures de redressement.

M. Gagnon: Je vous ai suivi jusqu'à ce que vous parliez du manque de règlement. Vous dites que cela n'a pas été analysé. Qu'entendez-vous par manque de règlement et pourquoi cela n'a-t-il pas été analysé?

M. Hare: Ce qui est fascinant au sujet d'un réacteur nucléaire, c'est que tout est réglementé au pouce près. On n'a qu'à amener le réacteur jusqu'au point de criticité et à le maintenir à ce niveau-là, ou presque. Ce n'est pas comme si quelqu'un tenait une poignée. Tout est régi par ordinateur ou par une banque d'ordinateurs.

Si, pour une raison quelconque—comme une explosion dans la salle de contrôle, un tremblement de terre, ou quelque autre facteur externe—les ordinateurs de contrôle ne fonctionnent plus, cela cause évidemment une

[*Text*]

to be kept under tight control. That is what is meant here, and it is feasible, although it is exceedingly unlikely.

Mr. Gagnon: Why has it not been analysed, though? I do not understand that aspect.

Dr. Hare: It has been thought so extremely unlikely that it was not worth analysing. You see, these reactors have shut-down systems, and the theory is that the shut-down systems are damned nearly infallible. Why analyse things that are not going to happen?

There is a good deal to be said for this. It costs hundreds of thousands of dollars, if not millions of dollars, to do the experiments I am talking about here. I can tell you exactly what it cost us. My survey alone paid about $85,000 to Argon for their very small part of the study we asked Ontario Hydro to do.

Mr. Gagnon: In your summary technical report you say that, by 1993 when Darlington comes on, it will meet 69% of the consumption. Does this mean the nuclear plants of Ontario Hydro will be going beyond load level and into supplying peak power?

Dr. Hare: No, it is 69% of total consumption; it is 80% of base load.

Mr. Gagnon: So you do not anticipate Ontario Hydro doing as the French have and supplying peak power and following the load.

Dr. Hare: Hydro have no plans to do that yet. If they did have such plans, I think I would oppose those plans. I think nuclear power, by its very nature, is not only most economical but also probably safest if it is operated flat out; that is to say, if it is used with as few deliberate power excursions as possible. I prefer to think those reactors are humming away at a standard rate than having control systems that take them up and down all the time.

Mr. Gagnon: I have two last questions, if I may. First, you mentioned that CANDU makes tritium and carbon-14. Where does the carbon-14 come from, or where does the carbon come from? Second, what are your thoughts on the repository for spent fuel?

Dr. Hare: First of all, the carbon-14 comes from nitrogen-14. Unfortunately, the mistake was made, when the Pickering "A" reactors were designed, of putting into the annulus between the pressure tube and the calandria tube the inert gas nitrogen-14, which is ordinary atmospheric nitrogen. Nobody noticed the fact that under neutron bombardment this would then... Let us see, I have forgotten the transition. I think it goes up to oxygen-17, which decays then alpha particle-wise and comes back down to carbon-14. It is a nuclear transition, in other words, that was not anticipated.

[*Translation*]

vive inquiétude puisque l'on a un système fonctionnant indépendamment, alors qu'il avait été jusque là soumis à une surveillance sévère. Voilà ce que nous entendons par là, c'est faisable, mais extrêmement improbable.

M. Gagnon: Pourquoi n'avez-vous pas analysé cette situation? Je ne comprends pas.

M. Hare: On l'a crue extrêmement improbable; aussi on n'a pas jugé bon de l'analyser. Voyez-vous, les réacteurs sont dotés de systèmes d'arrêt des machines, et théoriquement on les estime quasi-infaillibles. Dans ce cas, pourquoi analyser ce qui ne se produira pas?

On aurait beaucoup à dire sur le sujet. Il peut en coûter des centaines de milliers de dollars, sinon plus, pour faire les expérience dont je parle ici. Je peux vous dire exactement ce que cela nous a coûté, à nous. La toute petite partie de l'étude que nous avons demandée à Hydro-Ontario a rapporté environ 85,000$ à Argon.

M. Gagnon: Dans le résumé de votre rapport technique, vous dites que d'ici 1993, date à laquelle la centrale de Darlington sera fonctionnelle, vous pourrez répondre à 69 p. 100 de la consommation. Cela signifie-t-il que les centrales nucléaires d'Hydro-Ontario dépasseront le niveau de charge prévu et atteindront la puissance de crête d'approvisonnement?

M. Hare: Non, il s'agit de 69 p. 100 de la consommation totale et de 80 p. 100 de la charge de base.

M. Gagnon: Vous ne vous attendez donc pas à ce qu'Hydro-Ontario fasse comme les Français et fournisse la puissance de crête pour suivre la charge demandée?

M. Hare: Hydro-Ontario n'a pas l'intention de le faire, à l'heure qu'il est. Même si elle en avait l'intention, je pense que je m'y opposerais. De par sa nature même, l'énergie nucléaire est non seulement la plus économique, mais probablement aussi plus sécuritaire, dans la mesure où elle est exploitée avec le moins possible d'excursions de puissance délibérées. Je préfère que les réacteurs fonctionnent à la même puissance de façon constante plutôt que d'avoir à leur adjoindre des systèmes de contrôle pour vérifier les fluctuations.

M. Gagnon: J'ai deux dernières questions à vous poser. Tout d'abord, vous avez dit que le CANDU produisait du tritium et du carbone-14. D'où provient le carbone, et plus particulièrement le carbone-14? Deuxièmement, que pensez-vous des dépôts de combustible épuisé?

M. Hare: Tout d'abord, le carbone-14 provient de l'azote-14. Malheureusement, on a fait une erreur lorsque l'on a dessiné les réacteurs de la centrale Pickering «A»: on a introduit dans l'espace annulaire entre le tube de force et le tube de calandre le gaz inerte, azote 14, qui est l'azote ordinaire trouvé dans l'atmosphère. Personne ne s'est rendu compte que, avec un bombardement de neutrons, cela... Attendez, j'ai oublié quelle était la séquence de transformation. Je pense que le gaz se transforme en oxygène 17, qui libère ensuite des particules alpha et se retrouve ensuite sous la forme de

[*Texte*]

I have had personal experience of this because I actually did put on the protective clothing and get right inside those Pickering "A" reactors and look at what they were actually doing. The workers had to work in very undesirable levels of carbon-14. They wore extra, extra layers of protective clothing as a result.

They have gotten over the problem now in that all subsequent reactors have used ordinary carbon dioxide as the gas, and oddly enough, if you irradiate carbon dioxide it does not produce any significant quantities of carbon-14. It is nitrogen that is the problem.

The second question was what?

Mr. Gagnon: Repository for spent fuel.

Dr. Hare: I believe it is perfectly feasible—and it should be done—to build an underground repository in a remote location to get it out of people's hair and anxieties, and that it is possible to design a safe means of transporting the fuel to those repositories. I could stay here for the rest of the day answering the details behind that, sir, because this is one that I did in my report to the federal government in 1977 and I have not changed my mind.

Meanwhile, the fuel stays on the sites, and it can do so indefinitely if that is what the public wants. But I think the public is wrong if the public thinks that is a good idea. I would like to see this stuff concentrated in repositories. I would like to see the program that Hydro and AECL are carrying out put into progress. I think they have done a very good job, incidentally, of investigating the possible sites. It will be extremely difficult to find a final site that would be acceptable to the public because of the unpleasant reputation the stuff has. I personally feel nevertheless it should be done. It is one of those awkward things. You cannot have reactors without being able to dispose of the fuel.

• 1345

The Chairman: We feel exactly the same way and I think one of our strongest recommendations is going to be, mainly through public relations, that there has to be a repository, some sort of disposal site set. It was a matter of, let us get our act together and put a time limit on it. We think the public does not want to accept nuclear energy in regards to electric power mainly because of the repository, the storage and the disposal systems.

Dr. Hare: My attitude is typical in this. Most scientists—I am not talking about biological scientists; I am talking about physical scientists, like myself—and engineers would say that the major problem is that of reactor safety. One of the reasons I agreed with the

[*Traduction*]

carbone-14. C'est une transition nucléaire, autrement dit, imprévue.

J'ai vécu personnellement cette situation, parce que j'ai moi-même visité l'intérieur des réacteurs de Pickering «A» pour regarder ce qui s'y faisait, et j'ai été moi-même obligé de revêtir les combinaisons protectrices. Les employés qui y travaillaient y étaient en contact avec des niveaux beaucoup trop élevés de carbone-14; aussi portaient-ils des couches supplémentaires de vêtements protecteurs.

On a aujourd'hui résolu ce problème, car tous les autres réacteurs construits ultérieurement utilisent le gaz carbonique ordinaire et, ce qui est assez curieux, si l'on irradie le gaz carbonique, il n'émet pas de grandes quantités de carbone-14. C'est l'azote qui causait le problème.

Quelle était votre deuxième question?

M. Gagnon: Le dépôt de combustible irradié.

M. Hare: Je crois qu'il est tout à fait possible—ce qui devrait se faire—de construire un dépôt sous-terrain dans un endroit très éloigné pour que cela n'inquiète plus personne; il est aussi tout à fait possible de mettre au point des moyens absolument sécuritaires pour transporter le combustible jusqu'à ces dépôts sous-terrains. Je pourrais vous expliquer cela en détail jusqu'à ce soir, parce que j'ai justement, sur ce sujet, rédigé un rapport que j'ai remis au gouvernement fédéral en 1977, et je n'ai pas changé d'avis depuis.

Entre temps, on peut garder le combustible sur place, et cela indéfiniment, si le public le souhaite. Mais je pense qu'il a tort de penser que c'est la meilleure solution. Je voudrais que ces produits soient enfouis dans des cimetières. J'aimerais que le programme établi par Hydro-Ontario et l'EACL avance. Je dois dire qu'ils ont fait tout ce qu'ils ont pu pour trouver des sites d'enfouissement éventuels. Il sera très difficile de trouver un site définitif acceptable pour le public à cause de la mauvaise réputation de ces déchets. Personnellement, cependant, je pense que cela devrait être fait. Ce n'est pas facile, mais il faut le faire. On ne peut pas construire de réacteur sans pouvoir évacuer le combustible un jour ou l'autre.

La présidente: Nous sommes entièrement du même avis, et je crois que, dans notre rapport, nous mettrons surtout l'accent sur l'obligation de faire accepter, par relations publiques, la nécessité d'avoir un cimetière, un site d'enfouissement des déchets. Prenons une décision une fois pour toutes et imposons un délai. Nous croyons que le public rejette l'électricité produite par l'énergie nucléaire parce que justement il faut trouver un endroit où déposer, évacuer et enfouir ces déchets.

M. Hare: Ce que je pense à ce sujet est typique. La plupart des scientifiques—et je ne parle pas des biologistes, mais des physiciens, comme moi-même—et des ingénieurs vous diront que ce qui importe avant tout, c'est la sécurité du réacteur. Si j'ai accepté le poste que

[*Text*]

Minister to do this job was that I have always felt that reactor safety was the main problem. But I agree with you: I think the public is more impressed by the fact that these reactors produce long-term dangerous risks; that is what has the public appeal. But I do feel that there is no choice; the public will ultimately have to agree to having this stuff disposed of, even if it is only disposed of on the site, but I would very much sooner take the fuel and put it down a deep hole somewhere in a remote location than put it right under Pickering or right under Darlington, which is what will have to happen if nobody will agree to it being moved or agree on another site.

Mr. Gagnon: What sort of criteria would you have for site selection?

Dr. Hare: Certainly my first would be acceptability by the local population. I just do not think anything of this kind can be wished on an unwilling constituency. I would not do it.

Mr. Gagnon: Okay, secondly?

Dr. Hare: Hard igneous rock, available in great depth.

Mr. Gagnon: What is wrong with anhydrate or salt deposits, for instance?

Dr. Hare: I do not think salt deposits exist in this country at suitable positions. If they do, I think they are apt to be honeycombed with pre-existing workings. I prefer the massive igneous to the salt.

Mr. Gagnon: Certainly much of southern Saskatchewan has very thick salt beds. Michigan and southern Ontario have salt beds that have been there for the last 350 billion years.

Dr. Hare: But the southern Ontario beds are indeed honeycombed with pre-existing workings and they are not secure. The Saskatchewan ones are too far away; besides, if I were a Saskatchewan farmer I should say why bring it all this way?

Mr. Gagnon: So part of your criteria then would be that it is close to the place where it is being used, if you are ruling out Saskatchewan—

Dr. Hare: Yes, minimize transportation. It has to be, in my opinion, rail transport.

Mr. Gagnon: What about sea transportation?

Dr. Hare: We do not have the sea.

Mr. Gagnon: You have an inland sea with the Great Lakes.

Dr. Hare: Yes, but the Great Lakes have canals and narrows and locks and accidents, sea wrecks. I do not think I want to see this stuff move on the Great Lakes. Mind you, the containers are very secure indeed. I have actually been in one.

[*Translation*]

me proposait le ministre, c'est précisément parce que j'ai toujours pensé que cette question de sécurité était au coeur du problème. Mais je suis d'accord avec vous, le public est davantage impressionné par le fait que ces réacteurs présentent un danger à long terme; c'est ce que pense le public. Mais à mon avis, nous n'avons pas le choix; le public devra au bout du compte accepter que ces déchets soient évacués, même s'ils ne sont enfouis que dans un cimetière, bien que je préférerais qu'ils le soient au fond d'un trou quelque part dans une région éloignée plutôt que sous terre à Pickering ou à Darlington, ce qu'il faudra faire si personne n'accepte que ces déchets soient enfouis ailleurs.

M. Gagnon: À votre avis, quels critères devraient régir le choix de ces sites?

M. Hare: Le premier critère serait que ce site soit accepté par la population locale. Je ne crois pas que l'on puisse imposer cela à une population qui n'en voudrait pas.

M. Gagnon: Et le deuxième critère?

M. Hare: Sous des roches éruptives dures, à grande profondeur.

M. Gagnon: Que voyez-vous à redire à des mines déshydratées ou des mines de sel, par exemple?

M. Hare: Je ne crois pas qu'il y ait au Canada des mines de sel bien placées. S'il en existe, elles sont vraisemblablement criblées d'ouvrage de soutènement. Je préfère les roches éruptives au sel.

M. Gagnon: Mais on trouve des couches de sel très épaisses dans le sud de la Saskatchewan. Les couches de sel que l'on trouve au Michigan et dans le sud de l'Ontario existent depuis 350 milliards d'années.

M. Hare: Oui, mais les couches de sel qui se trouvent dans le sud de l'Ontario sont criblées d'ouvrages et ne sont pas sûres. Les couches de sel que l'on trouve en Saskatchewan sont trop éloignées; d'ailleurs, si j'étais un agriculteur de la Saskatchewan, je vous demanderais: pourquoi apporter ces déchets jusqu'ici?

M. Gagnon: Vous estimez donc que ces déchets devraient être enfouis près de la centrale puisque vous rayez la Saskatchewan. . .

M. Hare: Oui, en vue de réduire au minimum leur transport. Il vaudrait mieux que cela se fasse, à mon avis, par chemin de fer.

M. Gagnon: Et par mer?

M. Hare: Nous n'avons pas de mer.

M. Gagnon: Les Grands Lacs constituent une mer fermée.

M. Hare: Oui, mais il y a des canaux, des étranglements, des écluses dans les Grands Lacs, et aussi des accidents. Je ne voudrais pas que ces déchets soient acheminés par les Grands Lacs. Remarquez bien, les conteneurs sont vraiment très sûrs. J'ai déjà été à bord d'un de ces porte-conteneurs.

[*Texte*]

The Chairman: Most railways go through downtown, or major urban areas.

Dr. Hare: Then you would have to make railways that did not go downtown, madam, and it can be done. I mean, when I was doing this investigation I actually looked at routes between Bruce and Darlington and Pickering and northern Ontario that would not involve movement through downtown population densities of any great size.

In any case, we are talking about containers that will survive crashes of those trains at ten times the speed the trains are ever going to go at. Really, there is no question of security. I think, however, that I do not like the idea of hundred tonne steel containers moving on the highways, and that is why I have always preferred the rail.

Mr. Gagnon: It would certainly be hard on a road. We have acceptability by the population, granitic rocks and rail transportation. Presumably you would have to have earthquake-prone areas being ruled out.

• 1350

Dr. Hare: Yes, although I am not impressed by the earthquake hazard. Japanese coal mines, for example, are not greatly affected by the frequent major quakes. The earthquake damage is largely confined to the earth's surface; it is not very effective at depth. But you are talking here to a non-expert. It is my colleague, Les Chennault, and his people that you should be asking these questions of.

Mr. Gagnon: Since you had already looked at it, I just wanted to get some of your thoughts.

Would you have any objections to accepting other countries' waste if we had such a repository?

Dr. Hare: Speaking as an individual expert, no, I would not object. Speaking as a Canadian citizen who is conscious of living in a country of consent, I do not think I would want to do it, because I do not think anyone would consent to it. I think this is something we are going to have to face. It has to be done within the territories of the state concerned and I think within the territories of the province concerned. I think perhaps if you had a single reactor, as Quebec does and as New Brunswick does, I would make an exception to that if it could be negotiated. But the less you carry these materials across political boundaries, the less I think it raises these questions.

The Chairman: Saskatchewan has the uranium deposits. Ontario, Quebec and New Brunswick utilize nuclear energy for electricity.

[*Traduction*]

La présidente: Mais la plupart des compagnies ferroviaires traversent le centre-ville de grosses agglomérations.

M. Hare: Dans ce cas-là, il faudra construire des voies de chemin de fer qui ne passent pas par le centre-ville, madame, et c'est possible. Lorsque j'ai effectué cette enquête, j'ai trouvé des voies entre Bruce et Darlington, et entre Pickering et le nord de l'Ontario, qui ne passeraient pas par de grosses agglomérations.

De toute façon, en cas d'accident, les conteneurs sont plus sûrs que les trains, même à une vitesse dix fois supérieure à la vitesse actuelle. Il n'y a vraiment aucune question de sécurité. Cependant, je ne voudrais pas voir des conteneurs en acier de 100 tonnes sur nos autoroutes; c'est pourquoi j'ai toujours préféré le chemin de fer.

M. Gagnon: Les routes le supporteraient mal. Ainsi, vous pensez donc que premièrement, les sites en question devraient être acceptés par la population locale, deuxièmement, et que ces déchets devraient-être enfouis dans des roches granitoïdes et acheminés par chemin de fer. Je suppose qu'il faudrait également exclure toute région menacée par des secousses sismiques.

M. Hare: Oui, même si cela ne présente pas, à mon avis, de véritables dangers. Au Japon, par exemple, les mines de charbon ne sont pas touchées par les gros tremblements de terre qui secouent fréquemment ce pays. Les tremblements de terre causent des dommages surtout à la surface de la terre et non en profondeur. Mais je ne suis pas expert en la matière. Vous devriez poser toutes ces questions à mon collègue, Les Chennault, et à ses collaborateurs.

M. Gagnon: Puisque vous y aviez réfléchi, je voulais simplement savoir ce que vous en pensiez.

Vous opposeriez-vous à ce que le Canada accepte les déchets d'autres pays s'il possédait un cimetière d'enfouissement de déchets?

M. Hare: Personnellement, non, à titre d'expert je n'y verrais pas d'inconvénient. Cependant, en tant que citoyen canadien vivant dans un pays démocratique, je ne crois pas que j'en voudrais, car personne n'y consentirait. Mais nous devons y faire face un jour ou l'autre. Ces déchets doivent être enfouis sur le territoire de l'État en question et sur le territoire de la province en cause. Si une province ne disposait que d'un seul réacteur, comme c'est le cas du Québec et du Nouveau-Brunswick, je ferais une exception si cela pouvait être négocié. Mais plus vous enfouissez vos déchets chez vous, moins cela pose de questions.

La présidente: La Saskatchewan compte des mines d'uranium. L'énergie nucléaire sert à alimenter l'Ontario, le Québec et le Nouveau-Brunswick en électricité.

[*Text*]

Dr. Hare: I know. I have heard this argument made with great emphasis several times. I do not expect people to be entirely consistent in their assessment of these things. The dominant side of Saskatachewan politics is Regina and Saskatoon, followed by the farmers, and Cluff Lake and Cigar Lake do not make much impression on the political scene. I think that is right and proper.

I think, on the other hand, when somebody from Algoma says, why do you not do it here, we mined the stuff and we do not mind taking it back, I have a lot of sympathy for that. If communities in the Algoma district or in the Bancroft highlands argue along those grounds, then I think that is a fully rational thing.

The Chairman: Excuse me for just a moment, Dr. Hare. Are you able to stay for another 10 or 15 minutes?

Dr. Hare: Yes, I am.

The Chairman: Mr. Gagnon and perhaps Mr. Porter have other committees, and there is also the House, but on behalf of them, as well as myself, we want to really thank you very much for coming today. But we are going to continue on if both Paul and Bob have to leave.

We are scheduled for Tuesday morning at 8 a.m. in room 306 for the last meeting on our draft.

Mr. Clay: Dr. Hare, you refer to the fact that Pickering "A" is less well protected than newer stations. I was wondering if you could briefly outline a little bit of the evolution in the safety systems through the Pickering "A" and "B" and Bruce "A" and "B" units. What has driven those changes in the safety systems? Has it been something that AECB has prompted? Has it been a natural evolution in design by AECL? Since the Pickering pressure tube failure would have occurred after most of that design work and construction was already under way, I would just like your views on what has driven that evolution in safety.

• 1355

Dr. Hare: I am not fully aware of the story, because it is very hard to extricate. I think you might find that my colleague, Bob Bothewell, who is just publishing a book on AECL, knows the story in more detail than I do. But I can give you a rough outline.

It was obvious from the start that CANDU systems would have a positive void coefficient. That is to say, if there were any breach in the cooling system, reactivity would go up explosively. Accordingly, it was assumed from the beginning that a shut-down system would be necessary. The shut-down system at NRX, the experimental reactor at Chalk River, proved inadequate, because essentially it was not separate from the control system and too much under the control of the operator. There was a serious accident, one of the world's first serious accidents, as a result.

[*Translation*]

M. Hare: Effectivement. J'ai souvent entendu cet argument. Cependant, je ne m'attends pas à ce que les gens soient entièrement conséquents lorsqu'ils analysent ce genre de choses. En Saskatchewan, la politique se joue surtout à Regina et à Saskatoon, puis dans les régions rurales compte tenu du poids des agriculteurs, et Cluff Lake et Cigar Lake ne sont qu'un point sur l'échiquier politique. C'est très bien comme cela, d'ailleurs.

Cependant, lorsque quelqu'un d'Algoma dit: «Pourquoi ne pas le faire ici, nous avons exploité ce produit et nous ne voyons aucun inconvénient à le conserver», eh bien, cela me réjouit. Si c'est ce que veulent les localités de la région d'Algoma ou de Bancroft, je crois alors que c'est tout à fait rationnel.

La présidente: Excusez-moi un instant, monsieur Hare. Pouvez-vous rester 10 ou 15 minutes supplémentaires?

M. Hare: Oui.

La présidente: M. Gagnon, et M. Porter peut-être aussi, ont d'autres comités auxquels ils doivent assister, en plus de la Chambre, mais je voudrais, en leur nom, vous remercier d'être venu aujourd'hui. Cependant, nous allons continuer même si MM. Gagnon et Porter doivent partir.

Nous examinerons pour la dernière fois notre projet de rapport mardi matin à 8 heures, salle 306.

M. Clay: Monsieur Hare, vous avez dit tout à l'heure que la centrale nucléaire de Pickering «A» est moins bien protégée que les nouvelles centrales. Pourriez-vous nous dire, en quelques mots, comment a évolué le système de sécurité des centrales Pickering «A» et «B» et Bruce «A» et «B». Qu'est-ce qui y a entraîné la modification des systèmes de sécurité? Cela a-t-il été fait à la demande de la CCEA? Est-ce dû à l'évolution naturelle des techniques mises au point par l'EACL? Puisque la rupture du tube de force de la centrale Pickering se serait produite alors que l'essentiel des travaux techniques de construction étaient déjà en cours, je voudrais savoir ce qui, à votre avis, a entraîné cette modernisation des systèmes de sécurité.

M. Hare: Je ne sais pas tout à ce sujet, car il est très difficile de s'y retrouver. Vous constaterez sans doute que mon collègue, Bob Bothewell, qui publiera sous peu un ouvrage sur l'EACL, en sait davantage que moi à ce sujet. Cependant, je peux vous en donner un aperçu général.

Il était évident dès le départ que les réacteurs CANDU auraient un coefficient de vide positif, c'est-à-dire, qu'en cas de panne du système de refroidissement, ce serait l'explosion. En conséquence, un système d'arrêt a été prévu dès le départ. Le système d'arrêt à l'ANRX, le réacteur expérimental installé à Chalk River, s'est révélé insuffisant, car il n'était pas suffisamment isolé du système de commande et dépendait trop de l'opérateur, ce qui a entraîné un accident grave, un des premiers accidents graves intervenus dans le monde.

[Texte]

So late in the 1950s, early in the 1960s, when the overall dimensions of this country's CANDU program were being thought out, people such as George Lund, the key designer of these things in so many ways, set it out as a basic principle that you had to have shut-down systems that were independent, diverse, and outside the control of the operator, and they must be able to shut the reactivity off within a few instants of any detected error in the operation of the reactor.

Well, when the first of these were built by Hydro at Rolphton, with General Electric participation, and at Douglas Point, both were in comparatively remote situations. They had shut-down systems, and they had shut-down systems resembling the present shut-down system in many ways. But it was not at that time seen as quite the crucial question it was going to be when Hydro decided to build at Pickering, because Pickering was a different proposition. It was on the eastern outskirts of Toronto.

So the shut-down system number one that was built in was, based on previous experience, shut-down rods that would fall into the reactor automatically if any departure from normal operating conditions were detected. This would be an automatic process, independently of the operators. On the basis of this, the AECB granted an operating licence on the site, although they did have doubts about it. They were worried about the proximity to Toronto and the fact that Pickering was being built up rapidly.

There were arguments that a second shut-down system would be required. But since it was not in the design, the board argued for stronger containment and for the construction of a vacuum building; in other words, a central vacuum building that would be available if containment failed in any one of the four reactors that were licensed in the first instance. So the beginnings of the vacuum building, which is still unique to Ontario Hydro—nobody else has it, to my knowledge—were the anxieties of the board about the fact that there was only one shut-down system in the Pickering "A" units.

When Hydro applied for licences to operate at Bruce, and then subsequently again at Pickering "B", the board insisted that there be a second shut-down system of an entirely independent kind. It is in fact the system that injects gadolinium nitrate into the moderator and shuts the neutron flux off by a quite independent method. You must have seen this if you were at Bruce.

The Chairman: It is a poison.

Dr. Hare: That is right. The word "poison" is often used.

With this they maintained their demand for a vacuum building but somewhat lowered their requirements for the concrete containment, since it was felt that with two shut-down systems it was a much more remote possibility that there would be a serious failure at Bruce. So the

[Traduction]

Aussi, vers la fin des années 1950 et au début des années 1960, lorsque le programme CANDU du Canada était en cours de préparation, ceux qui en étaient responsables, et en particulier George Lund, l'homme clef de ce programme, ont décidé que les systèmes d'arrêt prévus devaient être indépendants, variés, ne pas dépendre de l'opérateur et arrêter toute réactivité quelques instants après la moindre erreur décelée dans le fonctionnement du réacteur.

Lorsque le premier de ces réacteurs a été installé par Hydro-Ontario à Rolphton, avec la participation de General Electric, et à Douglas Point, ils étaient tous deux relativement éloignés. Des systèmes d'arrêt avaient été installés, qui ressemblent beaucoup aux systèmes d'arrêt actuels. Mais à l'époque, cette question n'avait pas retenu autant l'intérêt que lorsque Hydro-Ontario a décidé de construire la centrale nucléaire de Pickering, car Pickering se trouvait dans la banlieue-est de Toronto.

Ainsi, s'inspirant de l'expérience acquise, le système d'arrêt qui a été installé prévoyait que des barres d'arrêt glisseraient dans le réacteur automatiquement en cas de panne. Ce serait automatique et ne dépendrait pas de l'opérateur. C'est ainsi que la CCEA a accordé au constructeur un permis d'exploitation, même si la Commission avait des doutes à ce sujet. Ce qui l'inquiétait, c'est que la centrale était très proche de Toronto et qu'elle était construite très rapidement.

Certains ont dit qu'un système d'arrêt de secours devrait être installé. Mais comme les plans ne le prévoyaient pas, la Commission a demandé qu'une aire de confinement plus stricte soit installée et qu'un bâtiment sous vide soit construit; autrement dit, un bâtiment central sous vide, au cas où le confinement ne se ferait pas dans un des quatre réacteurs dont la construction avait été autorisée. C'est ainsi que ce bâtiment sous vide, unique à Hydro-Ontario—personne n'en a construit d'autre, à ma connaissance—a été construit pour répondre à la crainte de la Commission, qui s'inquiétait que la centrale Pickering «A» ne comporte qu'un seul système d'arrêt.

Lorsque Hydro-Ontario a demandé à la Commission un permis pour construire la centrale nucléaire de Bruce, et ensuite la centrale Pickering «B», la Commission a alors insisté pour que soit installé un système d'arrêt de secours de type entièrement indépendant. D'après ce système, du nitrate de gadolinium est injecté dans le modérateur, et le flux de neutron est arrêté de façon tout à fait indépendante. Vous avez dû le voir lorsque vous avez visité la centrale nucléaire de Bruce.

La présidente: C'est un poison.

M. Hare: Vous avez raison, ce mot revient souvent.

La Commission a exigé de nouveau qu'un bâtiment sous vide soit construit tout en assouplissant les mesures qu'elle avait imposées au confinement sous ciment; elle estimait en effet que les risques de panne sérieuse à la centrale nucléaire de Bruce seraient peu élevés

[*Text*]

subsequent stations have all had these two shut-down systems, which are tested continually. They have had an excellent record in recent years. There is a detailed analaysis of all the accidental shut-downs and so on that have taken place in the appendix volume here, if the committee cares to examine them.

• 1400

In a nutshell then, it has been a process that has grown by negotiation between Hydro and the control board, which was brought into high focus by the decision to make the first station in the outskirts of Toronto.

The Chairman: Go ahead. I will not interject now. Sorry, Dean.

Mr. Clay: We were probably going to ask the same question. This does lead on to something we had discussed. Do you have any views on the advisability of constructing nuclear generating stations near major population centres?

Dr. Hare: I do not make a recommendation of this but in the report there is a sentence—it is in one of the annexes—which expresses my opinion about it. It is that it is wiser to build these stations in remote situations, because in the event that you have to evacuate, it does not make sense to have to evacuate Metropolitan Toronto. You could not evacuate Metropolitan Toronto. So it is just nonsense to put these stations near major concentrations of population. They should never have been built where they were built. The Darlington and Pickering sites bring up problems that could have been avoided if people had been thinking along different lines.

The Chairman: Compared with Bruce.

Dr. Hare: Bruce is ideal.

The Chairman: Yes.

Mr. Clay: Of course, the Mississauga rail disaster highlighted that with the evacuation of 250,000 people.

Dr. Hare: That is it. I do not find any villains in this, however. The people who made these decisions will point out to you that the decision was taken in order to minimize cost. One of our intervenors referred to this as the cupidity of Ontario Hydro, but Ontario Hydro is us in the sense that it is a publicly owned corporation and the minimization of cost is part therefore of a sort of public effort in this thing. I still think it would have been a damned sight better to pay an extra couple of cents on my bill and put the thing somewhere where the evacuation phenomenon would not have presented the problems it does for Pickering and will later for Darlington.

Mr. Clay: To your knowlege, was the reason for the utility locating Pickering and Darlington so close to Toronto simply to reduce the transmission distance, the cost of the lines and the line losses?

[*Translation*]

puisqu'elle disposait de deux systèmes d'arrêt. Depuis lors, toutes les centrales nucléaires construites disposent de ces deux systèmes d'arrêt, qui sont testés régulièrement. Il n'y a pas eu d'accident au cours des dernières années. Si cela vous intéresse, vous trouverez en annexe une analyse détaillée de tous les arrêts accidentels qui ont eu lieu.

En un mot, cette procédure a vu le jour grâce aux négociations entre Hydro et la commission de contrôle, et on en a beaucoup parlé à cause de la décision visant à construire la première centrale dans la banlieue de Toronto.

La présidente: Allez-y. Je ne vous interromprai plus. Désolé, Dean.

M. Clay: Nous allions sans doute poser la même question. Cela nous amène à une question dont nous avons discuté. À votre avis, est-il sage de construire des centrales nucléaires près des grands centres urbains?

M. Hare: Ce n'est pas ce que je recommande, mais dans le rapport, ou plutôt dans l'une des annexes, il y a une phrase qui exprime mon opinion à ce sujet. Il vaut mieux, selon moi, construire ces centrales dans des endroits éloignés, parce que en cas d'évacuation, il serait absurde de devoir évacuer toute la région métropolitaine de Toronto. Ce serait impossible. Il est donc absurde d'installer ces centrales près des grands centres de population. Ces installations n'auraient jamais dû être construites à ces endroits. Les sites de Darlington et de Pickering causent des problèmes que l'on aurait pu éviter si les gens avaient réfléchi un peu plus.

La présidente: Par rapport à Bruce.

M. Hare: Bruce est un site idéal.

La présidente: En effet.

M. Clay: Bien sûr, la catastrophe ferroviaire de Mississauga a fait ressortir le problème puisqu'il a fallu évacuer 250,000 personnes.

M. Hare: Exactement. Il n'y a pourtant aucun coupable en l'occurrence, à mon avis. Les gens qui ont pris ces décisions vous préciseront qu'ils cherchaient avant tout à limiter les coûts. L'un de nos intervenants a parlé de la cupidité de Hydro-Ontario, mais cette entreprise nous appartient, d'une certaine façon, puisqu'elle est nationalisée et que tout le monde veut réduire les frais au maximum. Je continue à penser qu'il aurait mieux valu que ma facture soit un peu plus élevée et que la centrale soit installée à un endroit où l'évacutation n'aurait pas posé de problème comme ceux qui se posent à Pickering à l'heure actuelle et se poseront plus tard à Darlington.

M. Clay: À votre connaissance, a-t-on décidé de choisir les sites de Pickering et de Darlington qui sont si proches de Toronto uniquement pour réduire la distance de transmission de l'énergie, le coût des lignes et les pertes relatives à celles-ci?

[*Texte*]

Dr. Hare: That is what I have been informed, but I am not privy to what really went on. I was not doing historical research, like my colleague, Bothwell. I was trying to get at the present situation. But my understanding is this was cost minimization, from which point of view it makes a great deal of sense. You have to remember, too, that Hydro has a heck of a time getting permission to build a new transmission line.

The Chairman: That is exactly what I was going to bring up from Bruce.

Mr. Clay: I will just pose one more short technical question and then Mr. Harris would like to ask you a different type of question. Just returning to the safety systems for a moment, what was the reason that a moderator dump was included in some reactor systems but not in others?

Dr. Hare: The moderator dump went into Pickering "A" because it was a very convenient way of shutting down the reactor. Don Hurst, the former president of AECB, refers to Pickering having one and a half shut-down systems because the moderator dump is a very effective way of stopping the reaction. However, it takes some seconds to become effective and it is the first five seconds that matter in a nuclear accident and it is not effective then. It would not be effective in controlling LOCA events. For that reason, and the much more compelling reason that the moderator serves a useful purpose as a heat sink if it remains where it is, that in subsequent reactors they have not equipped it. They want to keep the moderator there to serve as a heat sink and it seemed to me to be good logic.

You understand, you are talking to a person who knew not a damned thing about this 15 months ago. I have had to educate myself. You really ought to be asking these questions of the experts who actually built these things.

The Chairman: You are certainly a tremendous resource of information and you are talking to somebody who knew nothing about it as well, but I cannot match your—

Dr. Hare: I was once described as the greatest master of the inaccurate biblical quotation living.

The Chairman: That is good. Do you have any more, Dean?

Mr. Clay: No. Thank you, Dr. Hare.

The Chairman: Mr. Harris.

Mr. Lawrence Harris (Consultant to the Committee): Dr. Hare, I feel obliged to declare my membership in the club of untrained scientific people, but it is certainly a very great opportunity to ask some questions of you.

[*Traduction*]

M. Hare: C'est ce que l'on m'a dit, mais je ne sais pas ce qui s'est vraiment passé. Je n'ai pas fait de recherche, comme mon collègue Bothwell. Je voulais voir ce qu'il en était à l'heure actuelle. Toutefois, d'après mes renseignements, la réduction des coûts a été l'objectif principal, ce qui me parait tout à fait logique. Il ne faut pas oublier non plus que Hydro-Ontario a beaucoup de mal à obtenir l'autorisation de construire une nouvelle ligne de transmission.

La présidente: C'est exactement ce que je voulais dire au sujet de l'installation de Bruce.

M. Clay: Je voudrais poser brièvement une autre question technique, et M. Harris aura une question différente à vous poser. Pour en revenir pendant quelques instants sur le système de sécurité, pour quelles raisons a-t-on installé une décharge de modérateur dans certains réacteurs, mais pas dans d'autres?

M. Hare: L'installation Pickering *A* a été dotée d'une décharge de modérateur parce que c'était un moyen très commode de fermer le réacteur. Don Hurst, ancien président de la CEAC, prétend que la centrale de Pickering a un système et demi de fermeture puisque la décharge de modérateur est une façon très efficace d'arrêter la réaction. Cependant, il faut quelques secondes pour que l'effet se produise, et ce sont les cinq premières secondes qui importent dans un incident nucléaire, et ce système n'est pas efficace au cours de cette brève période. Il ne permettrait pas de contrôler les cas d'A.P.R.P. Pour cette raison, et surtout parce que le modérateur est utile en tant que bassin de refroidissement s'il reste où il est, les autres réacteurs n'ont pas été dotés de ce système. On a voulu maintenir le modérateur là où il se trouve pour qu'il serve de bassin de refroidissement, ce qui me semble tout à fait logique.

Comprenez-moi, vous vous adressez à une personne qui ne connaissait rien dans ce domaine il y a encore 15 mois. J'ai dû m'informer tout seul. Vous devriez poser ces questions aux experts qui ont construit ces installations.

La présidente: Vous êtes sans nul doute une source d'information extraordinaire et vous vous adressez à quelqu'un qui ne connaissait rien à ce sujet non plus, mais je ne puis égaler votre. . .

M. Hare: On a dit un jour de moi que j'étais le plus grand spécialiste qui soit de la citation biblique inexacte.

La présidente: C'est bien. Avez-vous quelque chose à ajouter, Dean?

M. Clay: Non, merci, monsieur Hare.

La présidente: Monsieur Harris.

M. Lawrence Harris (conseiller auprès du Comité): Monsieur Hare, je me sens obligé d'avouer que je fais partie du club des scientifiques mais sans formation, je suis pourtant très heureux de pouvoir vous poser quelques questions.

[*Text*]

• 1405

My interests are more in the area of regulation and the financial spheres. I understood you to say that, because of the technical complexity of the CANDU design, you feel that it is unlikely or almost impossible to expect that there would be a significant CANDU sale to a large nuclear-committed country. Is that an across-the-board statement, or can you see circumstances where, for financial reasons, AECL would be able to look forward to sales in nuclear-committed countries soon?

Dr. Hare: I see no reason why a country that has not already made some kind of decision, does not have to choose, should not still want to buy a CANDU if that is what seems to be the way to go. CANDU reactors have a great deal going for them if you can afford the initial cost, and I suspect that this country would be very anxious to provide adequate credit to any such country.

The problem lies somewhat elsewhere. If you buy a pressurized water reactor, then the manufacturer will provide you in effect with all you need to get past your own regulating body. They will take on the job of getting past the regulating body. I do not think AECL has ever had the resources to be able to do that. Westinghouse have, and Westinghouse have been superbly good salesmen of their own products because they say in effect: do not worry about the regulators; we will fix them—not by bribery, because you certainly could not bribe the nuclear installations inspectorate, but by providing. . . The work is not done by CEGB to the same extent that it would be if they had put in our kind of reactor. So, because our reactor is so very special, virtually none of the work is transferable from the other technology. So we have to compete right up in front with salesmanship that includes the ability to answer all the questions the regulating body is likely to think of.

Mr. L. Harris: How large a task is that, and could you mention specific countries or buyers where, if that type of package were presented by AECL, there might be a high commercial probability?

Dr. Hare: I am really, obviously, out of my depth. The Japanese could do it obviously, but the Japanese have preferred to go to Babcock and Wilcox and Westinghouse. I think the Japanese enjoy the sensation of finding something from the United States they want to buy. There is another reason, in other words, why they would go to an American outfit.

A country such as Romania, which is starting from scratch and for a variety of reasons does not want to buy Soviet technology, is in a special position, and Romania in fact did buy the CANDU technology, though they unfortunately undertook to build it themselves, which was from their point of view a disaster. It should have been built by Canadian engineers. If it had then it would be fully operational by now. In that case, squaring the regulator was no great problem.

[*Translation*]

Je m'intéresse davantage à la réglementation et aux domaines financiers. J'ai cru vous entendre dire qu'étant donné la complexité technique du réacteur CANDU, il est peu probable, voire impossible, d'espérer une vente importante de ce réacteur à un grand pays nucléarisé. S'agit-il d'une déclaration générale, ou existe-t-il selon vous des cas où, pour des raisons financières, l'EACL sera en mesure d'espérer vendre bientôt des réacteurs à certains de ces pays?

M. Hare: Je ne vois pas pourquoi un pays qui n'a pas encore pris de décision, qui n'est pas obligé de choisir, refuserait toujours d'acheter un réacteur CANDU si c'est la meilleure chose à faire. Ces réacteurs présentent de nombreuses qualités si on peut se permettre de les acheter, et je suppose que notre pays n'hésitera pas à offrir un crédit suffisant à tout acheteur éventuel.

Le problème n'est pas là. Si l'on achète un réacteur à eau sous pression, le fabricant va vous fournir tous les éléments nécessaires pour obtenir l'accord de votre organisme de réglementation. Il se chargera de toutes les formalités nécessaires. Je ne pense pas que l'EACL ait jamais eu les ressources voulues pour le faire. Westinghouse les a, et cette société a obtenu d'excellents résultats dans la vente de ses produits parce qu'elle peut dire à ses clients: ne vous inquiétez pas des responsables de la réglementation, nous nous en occupons—non pas par la corruption, car il est impossible de corrompre les inspecteurs des installations nucléaires, mais en fournissant. . . Le CEGB ne fait pas le même genre de travail que s'il avait utilisé notre genre de réacteur. Ainsi, puisque notre réacteur est très spécial, pratiquement aucun des travaux n'est transférable de l'autre technologie. Nous devons donc soutenir la concurrence dès le départ en faisant preuve d'une compétence de vendeur, ce qui inclut l'aptitude à répondre à toutes les questions que l'organisme de réglementation est susceptible de poser.

M. L. Harris: Cette tâche est-elle vraiment importante, et pourriez-vous nous citer des pays ou des acheteurs précis avec lesquels, si l'EACL faisait ce genre d'offre, elle pourrait envisager de réaliser des ventes importantes?

M. Hare: Cela sort manifestement de mon champ de compétence. Le Japon pourrait de toute évidence le faire, mais les Japonais ont préféré s'adresser à Babcock et Wilcox et à Westinghouse. Le Japon prend un plaisir particulier à acheter quelque chose aux États-Unis. Il y a une autre raison, qui les amène à s'adresser à un fournisseur américain.

Un pays comme la Roumanie, qui commence à zéro et qui, pour des raisons diverses, ne veut pas acheter la technologie soviétique, se trouve dans une situation particulière; ce pays a effectivement acheté la technologie CANDU, même s'il a malheureusement entrepris de construire le réacteur lui-même, ce qui s'est révélé catastrophique à son avis. Le réacteur aurait dû être construit par des ingénieurs canadiens. Il serait alors déjà pleinement opérationnel. Dans ce cas, il n'a pas été

[*Texte*]

For most other countries we were not in time. Particularly Westinghouse, but to some extent the boiling water reactor people, got in there first with their package deals, and we were too slow, I suppose. I have talked to Bothewell about this a bit, but you are really talking to an amateur when it comes to the salesmanship on this. I have never tried to sell a reactor.

Mr. L. Harris: One reason for posing the question again is in the economic realm. Is there, in your eyes or from your standpoint, a compelling case to be made to subsidize AECL in building a demonstration reactor of a smaller scale, maybe a CANDU 300, with the thought in mind that if we can prove this is operating and can live up to the expectations then it is a much stronger tool for making sales? Is that a credible approach the way you see things?

Dr. Hare: If that could be done, for example, in Holland in collaboration with the Dutch authorities, I think it would.

Mr. L. Harris: Could you see it being done here in Canada?

• 1410

Dr. Hare: It seems to me that all you have to do to sell CANDU reactors is to bring people to New Brunswick and show them the world's leading reactor performer, Point Lepreau. They operate it with their own crew. It is a standing example of what can be done by a new administration if that administration is willing to accept the assistance of AECL in the first instance and then back off.

I do not see the point of, say, building on the soil of outer Mongolia or somewhere to demonstrate something when it can be seen by the people concerned right here in New Brunswick. I should mention Gentilly-2 in Quebec as well, but they might see Gentilly-1, and that would put them off permanently.

Mr. L. Harris: So you see no particular reason to show or demonstrate a smaller-scale CANDU. You feel that, for that purpose, the present unit at Point Lepreau is sufficient.

Dr. Hare: That is another matter. In the report I do say there are many reasons for preferring smaller units. It is true I suspect that a CANDU 300 will cost as much as a CANDU 600 in terms of the installed shut-down systems, or almost as much. You do not save very much from the point of view of public safety, which is what this document is about. But from the point of view of the economies of scale in production, I would have said the CANDU 300 would be competitive in many countries and in many situations with the power they are now

[*Traduction*]

difficile de convaincre les responsables de la réglementation.

Pour la plupart des autres pays, nous n'étions pas dans les temps. Westinghouse en particulier, mais dans une certaine mesure les fabricants de réacteurs à eau bouillante aussi, sont arrivés les premiers en offrant leurs contrats globaux, et nous avons trop traîné, je suppose. J'en ai parlé un peu à Bothewell, mais en matière de vente de réacteurs, je suis véritablement un amateur. Je n'ai jamais essayé de vendre un réacteur.

M. L. Harris: Ma question que je répète, est d'ordre économique. Existe-t-il, à votre avis, de bonnes raisons de subventionner l'EACL pour la construction d'un réacteur modèle à petite échelle, comme un CANDU 300, avec l'idée que si nous pouvons prouver qu'il fonctionne bien et qu'il atteint les objectifs visés, cela contribuera considérablement à accroître nos ventes? Est-ce, d'après vous, une bonne façon de procéder?

M. Hare: Si c'était possible, par exemple en Hollande, en collaboration avec les autorités hollandaises, je pense que oui.

M. L. Harris: Serait-ce possible au Canada?

M. Hare: Il me semble que tout ce qu'il faut faire pour vendre les réacteurs CANDU, c'est de faire venir les gens au Nouveau-Brunswick et leur montrer le réacteur qui a le meilleur rendement au monde, celui de Point Lepreau. Il y a une équipe là-bas qui le fait fonctionner. C'est un bon exemple de ce qu'une nouvelle administration peut faire si cette dernière est prête à accepter l'aide de l'EACL au départ et ensuite à s'en passer.

Je ne vois pas l'intérêt de construire quelque chose en Mongolie extérieure ou quelque part d'autre pour démontrer quelque chose qui peut être constaté ici au Nouveau-Brunswick. Je devrais également mentionner la centrale Gentilly-2 au Québec, mais il se peut qu'on aille voir Gentilly-1, ce qui découragerait tout le monde à tout jamais.

M. L. Harris: Donc vous ne voyez pas d'avantage à faire la démonstration d'un réacteur CANDU plus petit. Vous pensez que la centrale de Point Lepreau est suffisante.

M. Hare: C'est une autre question. Je dis dans le rapport qu'il y a bien des raisons pour lequelles les centrales plus petites sont préférables. Il est vrai, à mon avis, que les systèmes d'arrêt d'un CANDU 300 coûteront autant, presque autant, que ceux d'un CANDU 600. Il n'y a pas beaucoup d'avantages du point de vue de la sécurité du public, question qui fait l'objet de ce rapport. Cependant, du point de vue des économies d'échelle pour ce qui est de la production d'énergie, je dirais que le CANDU 300 serait concurrentiel dans beaucoup de pays

[*Text*]

producing, from what I see and what my friends in AECL now tell me.

Small is beautiful in my life. I have never liked big things, and that it not just a flip remark. I am very suspicious of the fact that power now has to be produced in 1,000-megawatt batches. I think that is a terrible way to produce power. Every time you want to vary the load you have to take these huge machines up and down and through the sequence. I would prefer to have smaller units on many grounds of security.

Mr. L. Harris: I would like to ask you one final question, which is very open-ended. In your experience with Ontario Hydro and AECL, can you offer any comments as to how costs might be shared, or do you have any insight in practical terms as to how AECL's financial outlook could be improved, any practical suggestions that might not be so obvious from where we sit?

Dr. Hare: I have no doubt that the costs of the support system that is required to run these reactors ought to include the cost of all the research and engineering facilities needed to keep those reactors efficient and safe, in which case the producing utilities ought to pick up the whole tab. If there is a case for AECL being financed federally in order to sell reactors overseas as part of this country's industrial thrust, so be it. But supposing that is not the case, then I can see no case for supposing that the federal government ought to go on paying for services that benefit certain provinces only. I would put the whole bill against Hydro-Québec and New Brunswick once the decision is taken that we are not going to be able to export this technology elsewhere.

I say so in the report. I say so for a very good reason. It seems to me, to come back to what we said earlier, madam, that there is a danger of a very important subject falling between the cracks on this. What matters is the safety of the public and the security of their electric supply. That is provided by these provincial utilities. The public pays for its power through the dues it pays to those utilities.

Ontario Hydro's revenues this year are $5.3 billion, and $2.5 billion come from the use of the CANDU reactor. It seems to me there is an adequate basis for saying that the Ontario consumer is very well able to pay for more of the research that is needed than happens at the present time. My friend, Bob Franklin, will kill me for saying that, but that is my opinion.

The Chairman: But on the converse, what is their debt, Dean?

Mr. Clay: It is approximately $25 billion of long-term debt.

[*Translation*]

et dans beaucoup de situations, d'après ce que j'ai pu constater moi-même et d'après ce que mes amis de l'EACL me disent maintenant.

J'ai toujours été contre le gigantisme. Je n'ai jamais aimé ce qui est grand, et ce n'est pas simplement une observation désinvolte. Je me méfie beaucoup du fait qu'il faut maintenant produire l'énergie par lots de 1,000 mégawatts. Je pense que c'est une façon affreuse de produire de l'électricité. Chaque fois qu'on veut varier la charge, il faut faire passer ces machines énormes par toutes les séquences de fonctions. Je préférerais avoir deux centrales plus petites pour beaucoup de raisons de sécurité.

M. L. Harris: J'aimerais vous poser une dernière question qui est très ouverte. D'après votre expérience avec Hydro-Ontario et le l'EACL, pourriez-vous nous dire comment on pourrait partager les coûts. Avez-vous des suggestions pratiques à nous faire sur la façon d'améliorer les perspectives financières de l'EACL? Avez-vous des suggestions pratiques à nous faire qui ne sont peut-être pas évidentes de notre point de vue?

M. Hare: Je suis convaincu que les coûts du système de soutien qui est nécessaire pour faire fonctionner ces réacteurs devraient englober le coût de toutes les installations de recherche et de génie nécessaires pour s'assurer que les réacteurs sont efficaces et sécuritaires. Dans ce cas, les services publics devraient payer toute la facture. Si l'on veut que l'EACL reçoive du financement du gouvernement fédéral afin de vendre des réacteurs à l'étranger dans le cadre de notre stratégie industrielle, qu'il en soit ainsi. Mais ce n'est pas le cas, je ne vois pas pourquoi on prendrait pour acquis que le gouvernement fédéral devrait continuer de payer des services qui ne profitent qu'à certaines provinces. Une fois qu'on décide qu'on ne va pas pouvoir vendre cette technologie à l'étranger, je ferais payer toute la facture par l'Hydro-Québec et le Nouveau-Brunswick.

C'est ce que je dis d'ailleurs dans le rapport, et pour de très bonnes raisons. Il me semble, pour en revenir à ce qu'on a dit tout à l'heure, madame la présidente, qu'il y a danger qu'un sujet très important passe au travers des mailles du filet. Ce qui importe, c'est la sécurité du public et la sécurité de son approvisionnement en électricité. L'électricité est fournie par les services publics provinciaux. Le public paie son électricité lorsqu'il paie la facture envoyés par les services publics.

Les recettes d'Hydro-Ontario de cette année sont de 5,3 milliards de dollars, dont 2,5 milliards de dollars proviennent de l'utilisation du réacteur CANDU. Il me semble qu'on peut prétendre que le consommateur ontarien peut très bien payer plus de coûts de recherche qu'à l'heure actuelle. Mon ami, Bob Franklin, va me tuer pour avoir dit cela, mais c'est mon opinion.

La présidente: Mais d'un autre côté, quelle est la dette d'Hydro-Ontario, Dean?

M. Clay: Elle est d'environ 25 milliards de dollars de dette à long terme.

[*Texte*]

Dr. Hare: Yes, $25 billion of long-term debt.

The Chairman: That is pretty staggering.

• 1415

Dr. Hare: It is staggering and it is our doing. Collectively it is our doing.

The Chairman: So you are suggesting then that the operating costs of AECL and their research should fall under the responsibility of the utilities in the provinces?

Dr. Hare: To the extent that it is required for safety purposes and for development purposes within the reactor systems itself.

Let us take the pressure tube issue. If there was no question at all of our ever being able to sell another CANDU reactor outside this country, that problem would be just as big as it is now. There are 20 power reactors either operating or about to operate here, each one containing, on an average, something like 430 pressure tubes per reactor. So it is clear to me that $19 million a year, which is the direct hydro contribution to that particular problem at the present moment, is below what is reasonable in the national context.

The Chairman: Just to wrap it up, obviously safety is the number one thing, but a lot more has to be done to inform Canadians regarding the acceptable safety of nuclear-generated power. I suppose the disposing of the spent fuel has to be number one. The Canadian Nuclear Association started three months ago an educational series of advertising on TV. It will be interesting to see the results of this after six months.

Dr. Hare: Well, I will tell you that it turns me off. I think it is being poorly handled. You mentioned *The Financial Post* supplement; nobody proofread it. It is shockingly put together. I think they go about it the wrong way. I have told them this.

The Chairman: What would you suggest, sir?

Dr. Hare: I do not particularly want to educate the public, madam. I recognize that is a shocking thing to say, but I am not in the business of educating the public. I am very much in the business of educating the technical and scientific community who know nothing about these reactors.

It is shocking to me that my own colleagues in the learned societies have a massive ignorance about these systems. We committed ourselves, more than any other political jurisdiction, except France and Belgium, to the use of nuclear power, and the scientific and technical communities overwhelmingly know next to nothing about the technology and its safety. I have found this very

[*Traduction*]

M. Hare: Oui, Hydro-Ontario a une dette à long terme de 25 milliards de dollars.

La présidente: C'est assez stupéfiant.

M. Hare: C'est stupéfiant et, collectivement, nous en sommes responsables.

La présidente: Donc, vous dites que les coûts de fonctionnement de l'EACL et les coûts de recherche devraient être payés par les services publics provinciaux?

M. Hare: Dans la mesure où ces coûts sont nécessaires aux fins de la sécurité et aux fins de la mise au point des systèmes du réacteur lui-même.

Prenons la question des tubes de force. Même si on ne pouvait plus vendre d'autres réacteurs à l'étranger, le problème serait tout aussi important qu'en ce moment. Il y a 20 réacteurs qui fonctionnent déjà ou qui sont sur le point de fonctionner ici, au Canada, et chacun d'entre eux contient en moyenne environ 430 tubes de force. Je trouve qu'il est donc évident que 19 millions de dollars, qui est la contribution directe que payent les services publics pour essayer de régler ce problème à l'heure actuelle, est en deçà d'une contribution raisonnable, compte tenu du contexte national.

La présidente: Pour terminer, il va sans dire que la sécurité est la première priorité, mais il faut faire beaucoup plus d'efforts pour informer les Canadiens au sujet du niveau de sécurité acceptable dans le domaine de l'énergie nucléaire. Je suppose que l'élimination du combustible irradié est également une priorité. L'Association nucléaire canadienne a commencé il y a trois mois à faire une série d'annonces à la télévision qui visent à instruire le public. Il sera intéressant de voir les résultats de cette expérience après six mois.

M. Hare: Je peux vous dire que je trouve que cette campagne n'est pas du tout impressionnante. Je pense que c'est très mal fait. Vous avez parlé de l'encart dans le *Financial Post*. Personne n'a corrigé les épreuves. La présentation est extrêmement mauvaise. Je pense que l'approche est mauvaise, et j'ai déjà dit cela aux responsables de cette campagne.

La présidente: Qu'est-ce que vous proposez, monsieur Hare?

M. Hare: Je ne tiens pas particulièrement à instruire le public, madame la présidente. Je sais que cela est assez fort, mais ce n'est pas mon rôle que d'instruire le public. Mon rôle est plutôt d'instruire les experts techniques et scientifiques qui ne savent rien au sujet de ces réacteurs.

Je trouve inadmissible que mes propres collègues des sociétés savantes soient parfaitement ignorants en ce qui concerne ces réacteurs. Le Canada s'est engagé, plus que tout autre pays, à l'exception de la France et de la Belgique, à utiliser l'énergie nucléaire, mais la vaste majorité des experts scientifiques et techniques ne savent rien au sujet de cette technologie ni des questions de

[*Text*]

discouraging. I accuse myself; I did not know what I was talking about prior to undertaking this investigation.

The Chairman: Then would you start at university levels?

Dr. Hare: Yes.

The Chairman: How would you do this?

Dr. Hare: Well, I do not know. For one thing I am going to challenge my colleagues. I am going to raise this matter in a big way through the Royal Society. Almost every day I hear somebody in one or other of the learned societies or some fellow of a society say something about the Canadian reactors which is just not the case. When a member of the public does this, I am sorry of course, but I do not blame the public in the least. I do not see any reason why the public should take a course in nuclear physics when it the electric light on. But when a physicist or a biologist or a medical scientist says something about this technology that is thoroughly misinformed, then I am shocked.

The Chairman: Whose responsibility should that be? Should it be the government, or AECB, AECL?

Dr. Hare: I guess individuals have a lot to do with it. People in the learned professions are so willing to express themselves strongly about issues that they do not really understand.

The Chairman: It is the same up on the Hill.

Dr. Hare: It baffles me. I have been doing it now because you have asked me to, but I do not go around posing as an expert on the nuclear industry. I think there is a very real function for people to do what I have just been forced to do; namely, to look at this because I was asked to; to deal with it dispassionately; and to try to come up with statements that are protective of the public interest.

• 1420

But the point is that the more normal reaction is to take strong positions, pro or anti some technology, without first having undertaken that. Having spent a year learning exactly how complicated a business this is, I am not inclined to do this ever again in any field. I propose to keep my mouth tightly shut about things I do not understand.

The Chairman: On that note, we want to extend our sincere congratulations on your report. You have certainly done an excellent job. I hope some of your colleagues in your profession, in your field of expertise, will heed your words and learn a bit more.

[*Translation*]

sécurité. J'ai trouvé cela très décourageant. Je m'accuse personnellement. Je ne savais pas de quoi je parlais avant de faire mon étude.

La présidente: Vous commenceriez par les universités?

M. Hare: Oui.

La présidente: Comment procéderiez-vous?

M. Hare: Je ne le sais pas. Je sais, cependant, que je vais lancer un défi à mes collègues. Je vais soulever cette question par l'entremise de la Société royale. Presque tous les jours, quelqu'un de telle ou telle société savante ou un membre d'une société quelconque dit quelque chose de faux au sujet des réacteurs canadiens. Lorsqu'un profane le fait, je le regrette, bien entendu, mais je ne le blâme pas. Je ne vois pas pourquoi le profane devrait suivre un cours de physique nucléaire lorsqu'il ouvre la lumière. Cependant, lorsqu'un physicien ou un biologiste ou un scientifique médical dit quelque chose de faux au sujet de cette technologie, je suis navré.

La présidente: Est-ce que cela devrait être la responsabilité du gouvernement, de la CCEA ou de l'EACL?

M. Hare: Je pense qu'en grande partie, c'est la responsabilité des gens qui font partie de ces sociétés savantes. Ils ont tellement tendance à se prononcer catégoriquement sur des questions qu'ils ne comprennent pas vraiment.

La présidente: C'est la même chose sur la colline du Parlement.

M. Hare: Cela me laisse perplexe. Moi, je me prononce catégoriquement parce que vous m'avez demandé de le faire, mais je ne prétends pas être expert en matière d'industrie nucléaire. Je pense qu'il est nécessaire que les gens fassent ce que je viens d'être obligé de faire; c'est-à-dire examiner toute cette question avec calme et essayer de faire des recommandations qui visent la protection de l'intérêt public.

Cependant, je tiens à souligner le fait que la réaction plus normale est de prendre des positions très fermes pour ou contre une technologie donnée sans avoir fait ce genre d'étude. Après avoir passé une année à apprendre la complexité de cette question, j'hésiterais à le refaire dans un autre domaine. J'ai l'intention de ne pas me prononcer sur les questions que je ne comprends pas.

La présidente: Sur ce, nous voulons vous féliciter sincèrement de votre rapport. Vous avez fait un travail excellent. J'espère que certains de vos collègues dans ce domaine vous écouteront pour en apprendre un peu plus.

[*Texte*]

As I said, we have been studying nuclear power for about nine or ten months now, and we share your concerns and a lot of your recommendations.

On behalf of my colleagues, I want to thank you for coming to Ottawa today and spending a couple of hours with us.

Dr. Hare: Thank you, Madam Chairman.

The Chairman: This meeting is adjourned.

[*Traduction*]

Comme je vous l'ai dit, nous étudions l'énergie nucléaire depuis environ neuf ou dix mois, nous partageons vos craintes et nous sommes d'accord avec beaucoup de vos recommandations.

Au nom de mes collègues, je tiens à vous remercier d'être venu à Ottawa aujourd'hui et d'avoir passé quelques heures avec nous.

M. Hare: Merci, madame la présidente.

La présidente: La séance est levée.

Canada Post Postage paid
Postes Canada Port payé

Book rate
Tarif des livres

K1A 0S9
OTTAWA

If undelivered, return COVER ONLY to:
Canadian Government Publishing Centre,
Supply and Services Canada,
Ottawa, Canada, K1A 0S9

En cas de non-livraison,
retourner cette COUVERTURE SEULEMENT à
Centre d'édition du gouvernement du Canada,
Approvisionnements et Services Canada,
Ottawa, Canada, K1A 0S9

WITNESS

From Ontario Nuclear Safety Review:

Dr. Kenneth Hare, Commissioner.

TÉMOIN

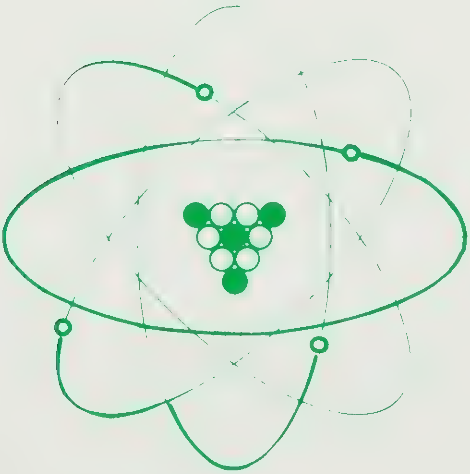
De l'Ontario Nuclear Safety Review:

M. Kenneth Hare, président.

Available from the Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Canada K1A 0S9

En vente: Centre d'édition du gouvernement du Canada, Approvisionnements et Services Canada, Ottawa, Canada K1A 0S9

NUCLEAR ENERGY UNMASKING THE MYSTERY



Barbara J. Sparrow

Chairman

Tenth Report

Standing Committee on

HOUSE OF COMMONS

CHAMBRE DES COMMUNES

Issue No. 48

Fascicule nº 48

Tuesday, June 21, 1988
Wednesday, June 22, 1988

Le mardi 21 juin 1988
Le mercredi 22 juin 1988

Chairman: Barbara Sparrow

Présidente: Barbara Sparrow

Minutes of Proceedings and Evidence of the Standing Committee on

Energy, Mines and Resources

Procès-verbaux et témoignages du Comité permanent

De l'Énergie, des Mines et des Ressources

RESPECTING:

Consideration of a draft report

CONCERNANT:

Considération de l'ébauche d'un rapport

Second Session of the
Thirty-third Parliament, 1986-87-88

Deuxième session de la
trente-troisième législature, 1986-1987-1988

Members of the Standing Committee on Energy, Mines and Resources

Chairman: **Barbara Sparrow, M.P.** — Calgary South

Vice–Chairman: **Aurèle Gervais, M.P.** — Timmins–Chapleau

Paul Gagnon, M.P.	—	Calgary North
Len Gustafson, M.P.	—	Assiniboia
Russell MacLellan, M.P.	—	Cape Breton–The Sydneys
Lorne Nystrom, M.P.	—	Yorkton–Melville
Bob Porter, M.P.	—	Medicine Hat

Clerk of the Committee

Eugene Morawski

Consultants to the Committee

Dean N. Clay
Lawrence Harris

Second Session of the Thirty-third Parliament

The Standing Committee on Energy, Mines and Resources has the honour to present its

TENTH REPORT

Pursuant to Standing Order 96(2), the Standing Committee on Energy, Mines and Resources undertook a study of the economics of nuclear power in Canada. After hearing evidence, the Committee has agreed to report to the House as follows.

NUCLEAR ENERGY

UNMASKING THE MYSTERY

Table of Contents

Table of Contents Continues...

Table of Contents (continued)

Foreword

In September of 1987, this Committee issued a report entitled *Oil – Scarcity or Security?* (Canada, House of Commons, Standing Committee on Energy, Mines and Resources, 1987) which presented the results of a year-long study of the future availability of conventional light crude oil. The report observed that Canada's output of conventional light oil will fall substantially in the future, with that decline to be offset either by rising imports of light crude or by a costly investment in the extraction and upgrading facilities needed to exploit Canada's large bitumen resource contained in the oil sands of Alberta. The development of frontier Canadian oil deposits was seen as offsetting only part of the decline in Western Canadian light crude production.

The study documented the growing shortfall in U.S. crude oil production relative to domestic consumption, a shortfall which raises serious concerns about U.S. national security. The report also examined the global distribution of recoverable petroleum resources, observing that the easily and inexpensively produced light hydrocarbons – light crude oil and natural gas – are concentrated in the Eastern Hemisphere (crude oil in the Persian Gulf and natural gas in the Soviet Union) while the hard to produce and costly to upgrade heavy hydrocarbon resources – heavy crude oil, bitumen and shale oil – are concentrated in the Western Hemisphere (heavy oil in Venezuela, bitumen in Canada and shale oil in the United States). Almost all of the world's current 10 million barrels/day surplus in oil-producing capacity is in OPEC and two-thirds of that surplus is in turn held by Persian Gulf producers. The principal finding of this study was that the stage is being set for yet another, more profound disruption in the international supply of light crude oil some years in the future.

In view of this finding and given rising concern about the environmental impact of fossil fuel use, the Committee decided to investigate a component of Canada's energy system which has attracted public debate but no comprehensive review by Parliament. Committee members agreed that a retrospective and prospective look at nuclear power development in Canada was warranted. This report presents the results of that examination.

Over the last 45 years, the scientific and engineering achievement of harnessing the nuclear chain reaction has been transformed in Canada into a unique reactor system with the world's best lifetime operating record. Despite this engineering success, Canada's nuclear power program continues to be challenged on various grounds. Public concern about reactor safety and environmental contamination was sharpened first by the 1979 Three Mile Island incident in the United States and then by the 1986 Chernobyl accident in the Soviet Union. Questions regarding the economic viability of nuclear-electric power generation are regularly raised. The Standing Committee on Energy, Mines and Resources therefore adopted the following mandate under Standing Order 96(2):

That the Committee conduct an examination of the economics of Canadian nuclear power and any matters pertaining thereto.

The study was begun in November 1987 with public hearings in Ottawa. The Committee soon realized that hearings alone would provide an insufficient basis on which to make recommendations in this complex field. Accordingly, the Committee supplemented its public meetings with visits to selected nuclear installations in Canada and with travel to Sweden, West Germany, France and the United States to examine the nuclear power programs of those nations in more detail. The cooperation which the Committee received during this travel allowed it to assemble information and gain impressions which would not otherwise have been available to it.

The Committee concentrated its investigation on the technical and economic aspects of Canadian nuclear development, including the nuclear-electric power program, the production of radionuclides for both medical and industrial applications, and the development of certain related technologies. These activities are interrelated and the Committee decided that they should be considered as aspects of the same issue. Other committees of the House of Commons have primary responsibility for studying environmental and health matters, so these elements of the nuclear question are referred to in less detail in this report.

The Committee presents 14 recommendations arising from its study. These are included in the section entitled Summary and Recommendations, which follows this Foreword. Dissenting statements by two of the Committee members are presented in Appendix A.

Many individuals and organizations assisted the Committee in its work, both within Canada and in the four countries visited by the Committee as part of this study. To those who shared their time and views with Committee members and staff, we are particularly grateful. Witnesses who appeared in public hearings are listed in Appendix B; those who contributed to the Committee's investigation during its travel are listed in Appendix C. The Department of External Affairs did a remarkable job of arranging the foreign travel on short notice.

The Committee also depended upon the abilities of its staff: on Dean Clay and Lawrence Harris of Dean Clay Associates for their consulting work; on the Committee Clerk, Eugene Morawski, and other staff from the House of Commons; on Diane Gagnon-Beaupré, Lucie S. Pilon and Georges Royer who prepared the French manuscript; and on the translators, who were faced with a demanding job.

Given the technical nature of nuclear development and the specialized terminology used by its practitioners, a list of abbreviations and acronyms is contained in Appendix D and a glossary in Appendix E. The report is extensively referenced because the subject of nuclear power is complex and because unfamiliar foreign sources of information were used in its preparation.

Summary and Recommendations

In the closing years of the twentieth century, global society has reached what one author has described as the "hinge of history". The increasing human population (estimated to have surpassed five billion in 1987), the massive shift to an urbanized pattern of human settlement and the continuing demand by all peoples for a higher standard of living are placing unprecedented stresses on our planet. Examples of environmental degradation have become so commonplace that reaction is difficult. What are the priorities for action? What are the consequences of not acting? What are the costs of remedial action? How can society better anticipate the environmental impact of various forms of development?

This Committee believes that some of the most profoundly disturbing aspects of environmental contamination are linked to society's growing exploitation of the Earth's energy resources. The emission of acid gases and of carbon dioxide to the atmosphere – both a product of the combustion of fossil fuels – are prime examples of contamination which is exceedingly difficult and costly to prevent. (1)

What society does in the remainder of this century to address these issues will fundamentally affect the quality of life that mankind will experience in the next century. Energy plays a pivotal role in determining this outcome – it is both part of the problem and part of the solution. All human activity depends upon the availability of energy in its various forms; all human exploitation of energy comes with its particular set of environmental consequences.

Although this study of nuclear development in Canada has had technical and economic issues as its primary focus, these broader environmental and social issues have coloured the Committee's thinking about the future contribution of nuclear power, within Canada and abroad.

The Committee wishes to make its position clear from the beginning: **maintaining the nuclear power option is vital to Canada's interests**, as it is vital to the interests of society in general. There is a compelling case to be made in support of continued nuclear development, a case based upon the future inadequacy of conventional petroleum resources and upon the environmental degradation arising from burning coal in progressively greater quantities for electricity generation. Unfortunately, in Canada neither the federal government nor the nuclear industry has articulated that case very well over the years and the public attitude has become ambivalent.

---

(1) When this report speaks of environmental contamination, it is referring to man-made contaminants, not to natural geochemical cycles which may already involve the same substances. Volcanic eruptions can inject sulphur dioxide into the atmosphere, for example, and carbon dioxide is a natural constituent of air. Of concern here is that society's activities have reached a scale where natural chemical cycles are being modified so extensively that the welfare of the human race is threatened.

The Committee's support for nuclear development is not uncritical – there are shortcomings in the Canadian nuclear program and there are problems inherent in the application of atomic energy. These must be weighed against the consequences of other forms of energy development, development which must satisfy diverse economic, social, environmental, strategic and technical ends. It is essential that such decisions and trade-offs be made by a well-informed public.

The onus of explaining nuclear power does not lie only with its proponents – opponents of nuclear power must also address difficult questions. Will the public and the environment be better protected by irretrievably dispersing huge quantities of sulphur dioxide, nitrogen oxides, carbon dioxide and other contaminants into the atmosphere, or by isolating relatively small quantities of radioactive wastes underground? What are the longer-term energy options open to society if nuclear fission is not exploited? How does one justify abandoning the huge investment in nuclear power and where will the resources come from to replace it with another form of generating capacity? What would Ontario substitute for the 50% of its electricity that it already derives from nuclear reactors?

The nuclear debate has been too narrowly focussed in Canada. It is not simply a question of whether to continue generating electricity with nuclear reactors. It is also a question of diminishing alternatives in electricity production, of the environmental consequences of not using atomic energy, of national energy security, of acquired scientific and engineering expertise, of spin-off technologies, and of employment for many Canadians.

As conventional oil and gas reserves are depleted and as the prime remaining sites for hydro-electric development are exploited, atomic energy will be increasingly looked to as an alternative means of producing electricity. The 1973-74 oil embargo educated Eastern Canadians about the danger of depending too heavily on imported oil for such purposes as electrical generation. Nuclear power is an economically attractive way of generating electricity today in certain parts of Canada, and in numerous countries which lack Canada's diversity in energy resources.

The environmental impact of burning larger amounts of fossil fuel, especially coal, to generate electricity has become alarming. Research is revealing the magnitude of the public health hazard, the enormous economic costs and the environmental destruction resulting from acid gas emissions from fossil-fuelled power plants. The implications of carbon dioxide accumulation in the Earth's atmosphere – an unavoidable accompaniment to fossil fuel combustion – are being studied intensively and the potential for disruptive climatic change is evident. Set against these concerns, the Committee finds nuclear power to be an environmentally appealing technology.

Nuclear power improves the security of energy supply in Canada, as most elements of our nuclear power program can be domestically supplied. Moreover, a substantial portion of Canada's research and development (R&D) capability is associated with the nuclear enterprise. Canada is not so well endowed with scientific

and engineering resources that it can afford to lose the pool of talent and the R&D facilities represented by our nuclear institutions.

There is an industry of almost 30,000 people whose employment is a direct consequence of Canadian nuclear development. This industry supports a domestically developed reactor system whose operating record continues to set the international standard among all reactor systems. Canada is the world leader in applying radionuclides to medical therapy; radiotherapy has prolonged the lives of millions of people in countries around the world. Canada is also in the forefront of radiation technology for industrial applications and in extending this technology to food irradiation, to wastewater treatment and to the sterilization of sludges containing disease-producing organisms. The Canadian nuclear program has also created technologies with application in non-nuclear fields, from screening individuals for their susceptibility to cancer to designing new O-rings for the U.S. shuttle launch vehicle. Quality assurance and quality control standards which Canadian manufacturers have had to develop as suppliers to the nuclear program have carried over to other product lines and strengthened the competitive position of Canadian companies.

Maintaining the nuclear option means ensuring that all parts of the enterprise are kept healthy – the federal component, led by Atomic Energy of Canada Limited (AECL) and the Atomic Energy Control Board (AECB); the provincial electric utilities that employ nuclear power generation; the private sector which provides the mining, processing, manufacturing and other support; and Canadian universities and colleges which supply professional and skilled personnel.

AECL is the federal crown corporation that promotes the use of nuclear energy. This corporation is composed of four divisions: (1) The Research Company which performs research, development and demonstration (R,D&D); (2) CANDU Operations which designs, constructs and markets CANDU nuclear reactors and which provides engineering services; (3) the Radiochemical Company which produces radionuclides for medical and industrial applications, and manufactures commercial and industrial irradiation equipment; and (4) the Medical Products Division which produces radiotherapy equipment.

AECB is the federal regulatory agency that controls the development, application and use of atomic energy in Canada, from the generation of electricity at power reactors through industrial radiography to the use of cobalt–60 in cancer treatment. AECB also participates on behalf of Canada in international measures of control. These measures include programs to prevent the proliferation of nuclear weapons through the diversion of nuclear materials.

Three provincial utilities operate power reactors today. They are Ontario Hydro in a program that now accounts for half of all the electricity generated in the province, Hydro-Québec and the New Brunswick Electric Power Commission. Despite this incorporation of nuclear generation into three electrical utility systems of central and eastern Canada, nuclear power is not economically competitive with coal-fired or

hydro-electric generation in all circumstances and in all regions of the country. In Alberta, for example, coal-fired generating plants located beside open-pit coal mines can produce electricity at a cost which nuclear plants simply cannot match. Given that coal firing will continue in some regions for the foreseeable future, it is particularly important that coal combustion technologies such as those described to the Committee by TransAlta Utilities be commercially deployed as rapidly as feasible, to minimize the environmental impact.

Canada holds extensive reserves of uranium and Saskatchewan's deposits are among the richest found anywhere. Uranium is mined in Ontario and Saskatchewan, and Canada exports more of this commodity than any other country. With uranium processing and reactor fuel fabrication also done domestically, Canada has established all of the steps in the nuclear fuel cycle needed to support the CANDU reactor system.

Despite this prominent position in the world nuclear industry, an adequate supply of professional and technical workers for the nuclear industry is not assured in Canada, as enrollment in nuclear-related educational programs continues to decline.

While supporting Canadian nuclear development in general, the Committee recognizes that there are deficiencies in specific aspects of that development. This report identifies a number of those deficiencies and makes recommendations addressing them. These recommendations are presented in the remainder of this section.

One of the Committee's foremost concerns is with the domestic program of radioactive waste management. Intensely radioactive materials are created in the course of nuclear-electric power production. In Canada, these high-level radioactive wastes take the form of irradiated uranium fuel bundles, currently being stored at each reactor site. Although storing spent fuel in water-filled concrete bays is quite satisfactory for a period of decades, the spent fuel must ultimately be disposed of in some final repository. This also applies to reprocessing wastes should Canada decide to recycle its irradiated fuel into new reactor fuel.

The Committee concludes that the concept of siting a final repository deep within a stable geological formation is an appropriate approach for Canada to take. Comparable work being carried out in other countries, especially in Sweden where the disposal program has many parallels with that of Canada, reinforces this conclusion. Yet public concern over radioactive waste management is perhaps the greatest single threat to the Canadian nuclear program. The public is not reassured when the deadline for concept verification is allowed to slip by a decade since the joint federal-Ontario radioactive waste management program was launched in 1978.

In the Committee's opinion, the schedule for the disposal component of the radioactive waste management program – which is a federal responsibility – must be advanced in Canada, not because the present methods of storing high-level

radioactive wastes are inadequate or inappropriate or unsafe, but to strengthen public confidence that the longer-term issue of disposal is being satisfactorily resolved. In particular, the disposal program through the concept verification and site selection/acquisition phases must be completed more quickly so that the public can be assured that both a means and a location for waste disposal have been identified. The Committee recognizes that expediting the high-level waste management program requires increased levels of funding in the short run. This is a modest price to pay for establishing such a critical component of the Canadian nuclear power program.

1. **The Committee recommends that the complete schedule for establishing a commercial, high-level radioactive waste repository be advanced, and that the additional funds necessary to expedite the program be made available by the Government of Canada.**

To monitor progress on this matter, the Committee directs the Atomic Energy Control Board to appear before it no later than June 30, 1989 and, in public testimony, present a revised timetable for establishing a disposal facility and a thorough description of the parameters by which the suitability of a site for the facility will be judged and the design and construction of the facility licensed. The Committee acknowledges that Atomic Energy of Canada Limited has established this timetable in the past but concludes that the program scheduling in future should be overseen by the regulatory agency. AECB must, of course, consult with AECL to ensure that the accelerated program is technically feasible. AECB must also allow sufficient time for the recently-announced Federal Environmental Assessment Review Panel to complete its comprehensive review of long-term nuclear fuel waste management. The Committee is convinced that a highly visible and vigorous program of radioactive waste management is crucial to maintaining public confidence in Canada's nuclear power program.

2. **The Committee directs the Atomic Energy Control Board to appear before it in public hearings, no later than June 30, 1989, to present an accelerated schedule for establishing a commercial disposal facility, together with a description of all the parameters which the Board will apply in licensing the site and the facility. The Atomic Energy Control Board will consult with AECL to ensure that the new schedule is technically feasible.**

The technical problems of radioactive waste management are not insurmountable: the Committee concludes that these wastes can be safely handled, stored, transported and disposed of providing the political will is there.

Canada's power reactors have been examined in several safety studies, most recently in the Ontario Nuclear Safety Review conducted by Dr. F. Kenneth Hare. In each case, the reactors have been judged to be acceptably safe. As Hare puts it, "The Ontario Hydro reactors are being operated safely and at high standards of technical performance...The risk of accidents serious enough to affect the public adversely can never be zero, but is very remote" (Ontario, Nuclear Safety Review, 1988c, p. i-ii).

The safety engineering of the CANDU reactor and the design concept of "defence in depth" provide assurance that this reactor system can be operated in Canada with a minimal level of risk both to utility personnel and to the public at large. Nothing the Committee learned in its testimony and travel seriously questions this judgement.

Nonetheless, the Committee has concluded that the limits of public liability on Canadian nuclear facilities are inadequate and must be raised. The current maximum liability on the part of the utility – $75 million for a multi-unit nuclear generating station such as Pickering A/B or Bruce B – is simply not sufficient. Nuclear suppliers have no public liability at all. While the Committee is not prepared to specify what those increased limits of public liability should be, it observes that today's coverage is neither realistic in terms of what the Three Mile Island and Chernobyl accidents cost (the liability claims arising from Three Mile Island have passed the billion-dollar mark and damages arising from Chernobyl are reportedly well in excess of two billion dollars), nor does it even approach the liability limits set in countries like West Germany and the United States. The fact that a serious accident which releases dangerous quantities of radioactivity to the environment is considered to be a very remote possibility does not mean that Canada should be unprepared to handle such an event.

3. The Committee recommends that the basic insurance coverage on Canada's nuclear facilities be raised substantially.

The lead agency for Canadian nuclear development is Atomic Energy of Canada Limited. AECL has provided and will continue to provide most of the R&D which underlies Canadian reactor design, development and safety. This crown corporation also markets Canadian reactor technology abroad and, in company with other international vendors, has been financially squeezed by the worldwide downturn in new power reactor construction. At the same time, the federal government is in the process of reducing AECL's funding in stages by a total of $100 million per year.

It is not appropriate, however, for the federal government to be reducing its financial support of AECL at this time. As the Committee heard in testimony and as Dr. Hare reported in his study, this reduction in funding is impairing AECL's ability to provide the R&D support required by Canada's nuclear-equipped utilities to continue the safe and reliable operation of their power reactors. This support is necessarily a continuing function for as long as the reactors operate. There is the prospect of greater financial self-sufficiency at AECL in the future, and the electric utilities which have benefitted so much from AECL's work may be in a position to increase their financial support. Even so, the federal level of funding should not be reduced. The Committee concludes that federal funding of AECL's operations should be increased and maintained at a higher level for at least the next five to ten years, giving this crown corporation an assurance of financial stability while it works to commercialize its various products and become more self-supporting. In no circumstances should a lack of funding be allowed to compromise the integrity of the existing reactor program.

4. **The Committee recommends that the Government of Canada increase its financial support of Atomic Energy of Canada Limited and guarantee that level of support for a minimum of five years.**

AECL is the premier institution for "big science" in Canada. Its scientific, engineering and technical skills are a national resource developed over a period of more than four decades. Atomic Energy of Canada Limited should be encouraged to continue its diversification into new areas of science and technology, accompanied by a program of public awareness to convey the significance of what it is doing.

5. **Atomic Energy of Canada Limited should be encouraged by the Government of Canada to expand its research and development activities, including non-nuclear R&D, as one of the primary scientific institutions in the country.**

AECL has nonetheless been slow to respond to a declining domestic and international market for reactor sales. Although AECL is now making major efforts to diversify its activities within the nuclear sector, valuable time has been lost. It is evident from the Committee's studies that future reactor sales in the international market will be much less frequent for some time to come, and intensely fought for by AECL, Framatome, Westinghouse, General Electric, Kraftwerk Union and other vendors. AECL cannot survive on the reactor business alone, but must diversify, and should be encouraged by the federal government to accomplish this as rapidly as feasible.

Because of the large front-end investment in money and time needed to construct nuclear reactors, uncertainty in predicting future demand for electricity causes utilities to be extremely wary about building new plants. Given the high carrying costs associated with delays in construction, it is imperative that future reactors be built in much less time (as is routinely achieved in France and Japan, for example). Means to expedite the design-licensing-construction process must be found. The standardized design of the CANDU reactor system should have been an important advantage in marketing. The Committee does not understand why that advantage has not been better exploited. Standardized designs have been used successfully in the French and West German reactor programs and allow for generic licensing by regulatory agencies.

The Committee encourages the Governments of Canada and New Brunswick to reach an agreement on the construction of a new CANDU 300 reactor at Point Lepreau. This project could be used as an opportunity to demonstrate the time savings of "up-front" licensing. This will be very difficult, however, unless the AECB's current manpower shortage is rectified.

The federal government proposes to privatize two divisions of AECL in the near future: the Radiochemical Company (RCC) and the Medical Products Division (AECL Medical). RCC produces radionuclides and irradiators for medical and industrial use and AECL Medical markets radiotherapy equipment. The Committee supports the objective of privatization but is concerned that AECL will be left with a core of basic and applied research which cannot become self-sustaining. Coupled with declining federal

funding for nuclear research and development, this would in the Committee's view cripple the research effort needed to sustain Canadian nuclear power development and to produce the next generation of reactor technology. Important R&D advances such as Chalk River's cancer-screening research might not find another home.

The Committee therefore recommends that AECL retain a minority interest in the Radiochemical Company, in the Medical Products Division and in the various Business Units as they are privatized. This provides for a modest but continuing income for AECL on the one hand; on the other, it provides the new entity with an R&D link to an internationally recognized corporation which should be valuable in future product development. The Committee further recommends measures that would restrict foreign ownership in these companies to a minority interest.

6. **The Committee recommends that the legislative mandate of Atomic Energy of Canada Limited allow the Corporation to hold a minority interest in any component of AECL which is privatized.**

7. **The Committee further recommends that any new entity created by privatization from Atomic Energy of Canada Limited be required to remain under Canadian control, although a minority foreign interest should be allowed.**

The Atomic Energy Control Board, which regulates nuclear activities in Canada, clearly lacks the manpower and financial resources to carry out its present responsibilities, let alone perform an expanded role. It is essential that nuclear power and the associated radionuclide business be well regulated to ensure their safe operation and that these activities be seen by the general public to be well regulated.

The Committee recommends that the Board's implementing legislation be modified to allow it to practice some measure of cost recovery, especially in its licensing operations. To the extent that cost recovery does not provide sufficient funds for the Board to fully discharge its responsibilities, the Committee also recommends that AECB's Parliamentary appropriation be adjusted to make up the shortfall. Increased support of the AECB would reduce delays being experienced in reviewing licence applications, and allow the Board to examine more thoroughly the submissions of licensees. The AECB also needs larger resources to expand its program of regulatory research. The Committee observes in this context that the U.S. Nuclear Regulatory Commission has been mandated by Congress to recover 45% of its $US 392.8 million 1988/89 budget through user fees. [The Parliamentary appropriation for the AECB in fiscal year 1988/89 is $24.4 million.]

8. **The Committee recommends that the *Atomic Energy Control Act* be altered to allow the Atomic Energy Control Board to practice cost recovery through licensing fees and charges for other user services as appropriate, provided that such fees do not unduly interfere with the Board's public dissemination of information.**

Testimony from the AECB itself, the recently-completed study by Dr. Hare on

reactor safety in Ontario and other sources all suggest that the Board is substantially deficient in money and manpower. The Committee accepts this evidence and doubts that cost recovery alone can fund expanded operations by the Board.

9. **The Committee further recommends that, to the extent the cost recovery measures instituted by the Atomic Energy Control Board fail to offset its cost of operations, the Board's Parliamentary appropriation be increased to ensure that all of its reponsibilities are fully and promptly discharged.**

Other aspects of the AECB's operations require attention. The Committee recommends that the AECB have its complement of full-time Board membership raised from one to five. This would allow more areas of specialization to be represented on the Board and better equip it to handle an increased volume of work. The Committee recommends that the Board adopt a higher public profile, opening all of its hearings to the public as one example. The Committee agrees with Dr. Hare's recommendation that AECB's advisory committees also be strengthened. To make the AECB more readily distinguishable by the public from AECL, the Committee further recommends that the AECB have its name changed, perhaps to the Nuclear Regulatory Board.

10. **The Committee recommends that Board membership at the AECB be increased from one full-time member to five full-time members, while maintaining the four part-time positions on the Board.**

11. **The Committee recommends that the Atomic Energy Control Board adopt a more public style of operation, including holding its hearings in public.**

12. **The Committee also recommends that the name of the Atomic Energy Control Board – AECB – be changed so that it is more readily distinguished by the public from that of AECL.**

There is an obvious need to educate the Canadian public about the benefits and costs of nuclear power. Much of the public debate about nuclear development is ill-informed and it serves everyone's interests that this situation be changed. The Committee believes that this task should be vested in a federal agency that is knowledgeable about the subject but removed from its promotion. The Committee sees the AECB as that agency.

13. **The Committee recommends that the Atomic Energy Control Board be directed to establish an office of public education dedicated to informing the Canadian public in an objective manner about the facts of nuclear development. The Government of Canada should ensure that this function receives adequate funding for the AECB to perform the task effectively.**

The cost of regulating the nuclear enterprise is comparatively high even in Canada, where nuclear regulation is far less obtrusive and prescriptive than in the United States. The reason is the unique standards applied by society to the generation

of nuclear power and to the management of radioactive wastes. These standards are much more rigorous than those applied to the operation of other energy systems and to the handling of other toxic materials, but are necessary to reassure the public. Nonetheless, an appropriate balance between regulation and regulatory costs should be sought. Opportunities to apply technology developed for radioactive waste management to the management of other toxic materials should be pursued by AECL.

Energy conservation/electricity demand modification has its place in utility planning, but in the longer run will not address all of the increase in electricity demand. Conservation and demand modification ease the pressure to construct new generating facilities, and should therefore be widely practiced, but are not in themselves a complete solution. The federal government should promote the more efficient use of electricity in those circumstances where the measures are cost effective and provide a positive economic return to all parties, but it should not be assumed that such efforts can entirely supplant the need for new generating capacity.

14. The Committee recommends that the federal and provincial governments cooperate more closely to identify opportunities where more efficient use of electricity could be achieved, and to promote those measures which can attain the greatest economic efficiency.

Private power generation is another approach to reducing the burden on utilities of financing new generating facilities. Given the mounting long-term debt being carried by Canada's electric utilities – almost $50 billion owed in total by Canada's two largest utilities – the way should be cleared of all unnecessary barriers to private power development, so that these producers can compete on economic terms. Whether or not private power generation will play a substantial role is very much a function of each utility's circumstances, but in principle the Committee supports the increasing contribution of electricity from this source.

The Committee notes the bid by the Government of Ontario for the province to become the location of the International Thermonuclear Experimental Reactor. This is a proposed collaboration by the United States, the Soviet Union, the European Community and Japan to build a large fusion test reactor, said to be the next major developmental step in fusion technology. Ontario has a strong case to make in support of its bid. The Bruce Nuclear Generating Station on Lake Huron provides both an excellent site and a source of electricity to operate a fusion reactor. Ontario Hydro's capability to supply tritium as a fuel for the fusion process is another enticement. The R&D, engineering and construction benefits would in turn be very welcome in Canada. Finland and West Germany are reported to have also bid for the project.

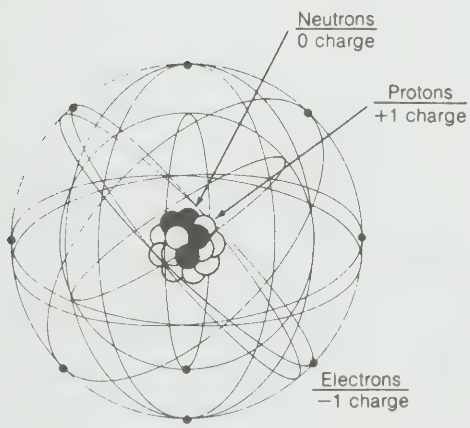
Atomic energy is not the evil genie in the bottle. Treated with respect and properly managed, it is a source of energy holding great promise for society's future. Canada's nuclear power program is well conceived and well run. With proper attention to the shortcomings noted by the Committee, nuclear power appears certain to play a larger role in Canada's energy system of the twenty-first century.

Reactor Systems

A. A Note on Atomic Physics

All matter – solid, liquid or gas – is composed of **atoms**, tiny "particles" that move around in perpetual motion. Most atoms are less than 2×10^{-8} centimetres (0.00000002 centimetres) in radius. The unit of measurement equal to 10^{-8} cm is called the angstrom, so atoms are typically less than 2 angstroms in radius. If an apple were magnified to the size of the Earth, then the atoms in the apple would be about the size of the original apple.

Once scientists established that all matter is composed of these particles or atoms, it was natural to ask, how many kinds of particles – **elements** – are there in nature? Ninety-one elements up to atomic number 94 (three elements in this sequence do not occur naturally) have been discovered. Hydrogen (H) is the simplest atom and is assigned the atomic number 1. Uranium (U), the element central to the nuclear power enterprise, has atomic number 92. To the naturally occurring elements, science has added another dozen or so artificially through nuclear reactions. All of these man-made elements are unstable and will sooner or later revert to a lighter, stable element.



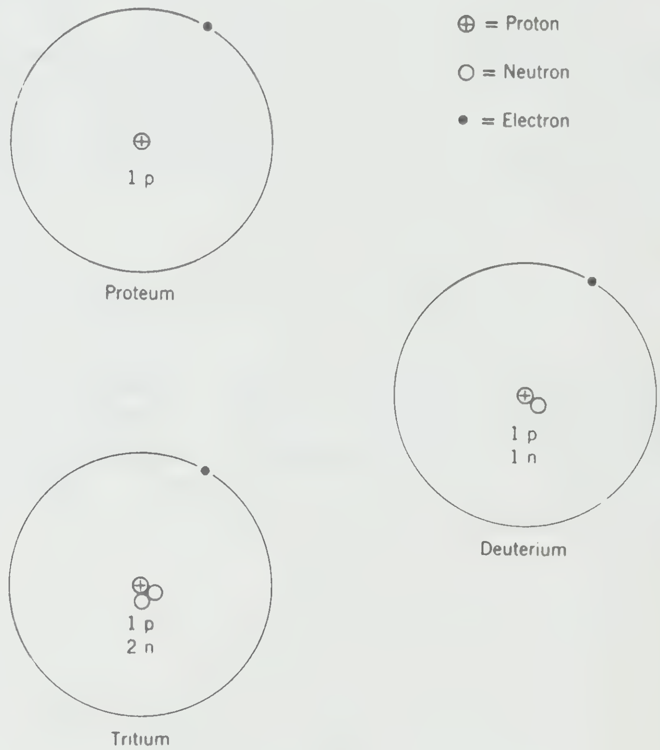
Atoms are in turn composed of three more fundamental particles: protons, neutrons and electrons. A tiny nucleus at the centre of the atom contains positively charged **protons** and electrically neutral **neutrons**. Protons and neutrons are much heavier than the third type of particle, negatively charged **electrons** which may be visualized as circling the nucleus in a spherical cloud. The nucleus represents only about 10^{-15} of the volume of the atom but almost all of its mass, like the sun in our solar system.

The sum of the number of protons and the number of neutrons in an atom is known as its **mass number**.

In their basic state, atoms contain equal numbers of protons and electrons and hence have a net electrical charge of zero. Under certain circumstances, atoms can gain or lose electrons, leaving them with a positive or negative electrical charge. Such atoms are said to be ionized. Radiation capable of stripping electrons from atoms is called **ionizing radiation**.

The number of protons determines the **atomic number** of the element and fixes its place in the Periodic Table. An atom with only one proton is always hydrogen; with eight protons is oxygen; and an atom with 79 protons is gold. Each element may vary, however, in the number of neutrons that it contains in the nucleus, and these differing versions of the same element are known as isotopes.

Hydrogen usually has one proton and no neutrons in its nucleus, and in this form is called protium. Less commonly, hydrogen contains one proton and one neutron, and is then known as deuterium. If the hydrogen nucleus contains one proton and two neutrons, it is in the unstable form called tritium. **Isotopes** are atoms with the same atomic number but a different mass number. The isotopes of hydrogen can be differentiated by writing them as hydrogen–1 (H–1), H–2 and H–3, giving the name of the element followed by its mass number. U–235 is the isotope of uranium used as the initial fuel in a nuclear reactor.



Each isotope of each element is an individual atomic species and each atomic species is known as a **nuclide**. There are some 104 known natural plus artificial elements but when all of their isotopes are added together, one discovers that there are more than 1,700 nuclides. To illustrate, there are 15 known isotopes of uranium (of which three occur naturally), so 15 of the 1,700+ known nuclides are forms of uranium.

Some elements, typically with large mass numbers, are unstable and disintegrate or "decay" naturally. **Radioactivity** is the spontaneous disintegration or fissioning of the nucleus of an unstable atom, accompanied by the release of energy. This spontaneous decay is not random – it proceeds at a specific rate characteristic of the radioactive nuclide (radionuclide) concerned. A unit for measuring radioactivity ("activity") is needed and that unit is the becquerel. One becquerel (abbreviated Bq) is one radioactive disintegration per second. [(1)]

---

(1) The becquerel has replaced the curie as the measure of radioactivity. A curie is defined as the radioactivity of one gram of radium and equals 3.7×10^{10} disintegrations per second. Since the becquerel is defined as one disintegration or decay per second, the correspondence between the units is: one curie = 37 billion becquerels, or one becquerel = 2.7×10^{-11} curie.

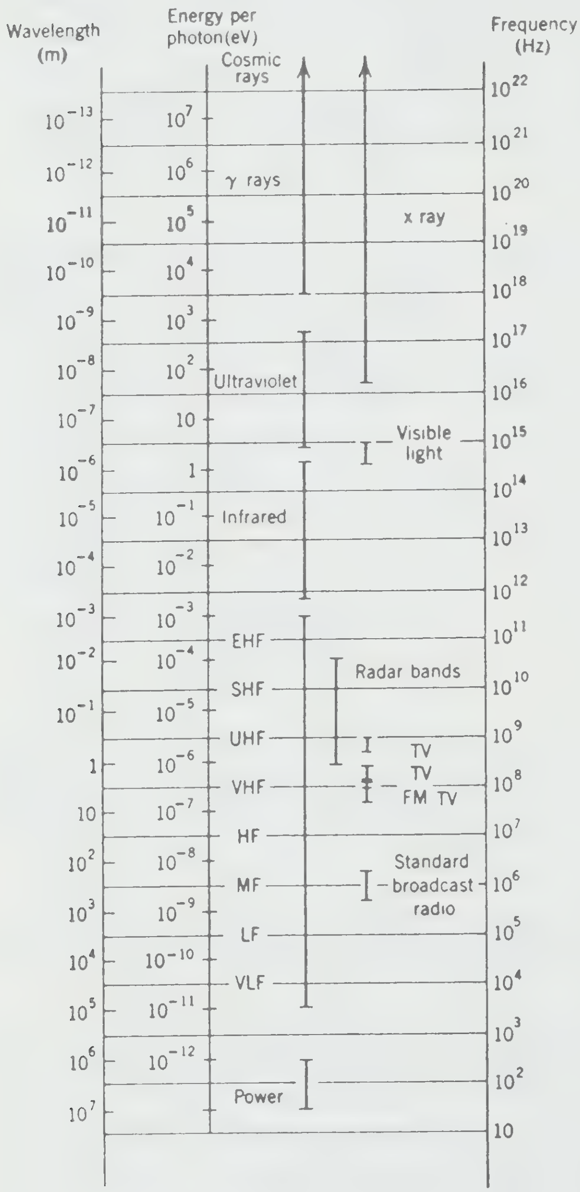
The **half-life** of a radionuclide is the time required for the activity (and thus the number of undecayed atoms) to decrease by 50%. After one half-life, one-half of the original substance and one-half of its original radioactivity remain; after two half-lives only one-quarter; and after 10 half-lives only 1/1024 remains. Half-lives of radionuclides can vary enormously. The half-life of oxygen–13 (an artificially produced radionuclide) is 0.0087 seconds while that of vanadium–50 (a naturally occurring radionuclide) is on the order of 6 quadrillion (6×10^{15}) years. To take more familiar examples, the half-life of tritium (hydrogen–3) is 12.4 years; that of uranium–238 is 4.51 billion years.

There are four naturally occurring radioactive decay sequences among the heavy elements, known as the thorium series, the neptunium series, the uranium series and the actinium series. The neptunium series is no longer observed in nature because the longest-lived element in the series (neptunium–237 with a half-life of 2.2 million years) has virtually completely decayed since the formation of the elements in the universe perhaps 15 billion years ago. In contrast, uranium–238 has not even gone through four half-lives since the calculated time of creation of the universe. There are also a number of isolated, naturally occurring radionuclides which do not belong to one of the heavy-element decay chains. Most notable are tritium and carbon–14 (which are continuously being created by cosmic ray bombardment of the Earth's atmosphere), potassium–40 and rubidium–87. A number of the naturally occurring radionuclides have been utilized for age-dating in geology and archeology.

Radioactive decay is accompanied by the release of one or more of four types of radiation capable of damaging living tissues: alpha particles, beta particles, gamma rays and neutrons. An **alpha** particle is a positively-charged helium nucleus (two protons and two neutrons) ejected from the nucleus of an unstable atom. A **beta** particle is a negatively-charged electron emitted from the nucleus of a decaying atom. A **gamma** ray is a specific quantity of electromagnetic radiation (photon) emitted by an atom as a result of a transition from one of its excited energy levels to a lower level. Gamma rays have neither mass nor charge.

Beta radiation has approximately 100 times the penetrating power of alpha radiation; gamma rays are 10,000 times more penetrating than alpha radiation. All four forms are capable of ionizing matter as they pass through it and consequently represent a biological hazard. Biological damage in humans may take the form of somatic effects – physical effects apparent in the individual who has suffered the radiation exposure – or genetic effects – effects which appear in the offspring of the exposed individual. Alpha emitters such as plutonium and radon gas are most hazardous when ingested or inhaled. Beta and gamma emitters, because of their greater penetrating power, are hazardous to humans both internally and externally. Exposure to high-energy neutrons is normally only a hazard in certain working environments around a reactor. All four types of radiation can be absorbed (as heat) in shielding materials like lead, concrete or water.

Figure 1: The Electromagnetic Spectrum



Source: Eisberg, Robert and Robert Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*, John Wiley & Sons, Toronto, 1974, p. 38.

Electromagnetic radiation refers to the emission or transfer of energy in the form of electromagnetic waves or particles. The electromagnetic spectrum extends from the longest radio waves to the shortest gamma rays, distinguished by their frequency of vibration. Society uses the electromagnetic spectrum for many purposes: sending electricity along transmission lines at a typical frequency of 50 or 60 cycles per second (50 or 60 hertz), broadcasting radio and television, radar, X–rays in cancer treatment and even solar radiation for skin tanning (with its risk of inducing skin cancers). The visible light detected by our eyes is part of this spectrum, bracketed by ultraviolet radiation at a higher frequency and infrared radiation at a lower frequency.

Figure 1 illustrates the electromagnetic spectrum and uses made of various bands in this energy spectrum.

Artificial radionuclides are created in nuclear reactors and particle accelerators when atoms are bombarded with highly energetic particles. They exhibit the same physical behaviour as those which occur naturally. For example, when plutonium–239 is created in a reactor, it begins to decay with its own characteristic half-life, which happens to be about 24,360 years. The sequence of nuclear changes which leads to the formation of plutonium within the reactor is:

uranium–238 + neutron —> uranium–239 + gamma ray

uranium–239 —> neptunium–239 + beta particle

neptunium–239 —> plutonium–239 + beta particle

The plutonium subsequently emits an alpha particle when it undergoes radioactive decay, and ends up as a stable isotope of lead.

The nuclei of atoms are held together by powerful electrical forces. When these nuclear forces are released, the energy involved is tremendous. **Fission** is a nuclear reaction in which a heavy nucleus splits into two parts (occasionally three) accompanied by the release of energy and two or more neutrons. Fission may be spontaneous, as in the decay of radioactive substances, or it may be induced by the capture of bombarding particles such as neutrons, the process exploited in a nuclear reactor. The fissioning of one kilogram of uranium–235 in a nuclear reactor releases approximately as much energy as can be obtained in burning 2,800 tonnes of coal. Atomic energy is the result of changes within the nucleus of the atom itself, while the heat liberated by burning the coal is the product of chemical changes only involving electrons on the outside of the atom.

A typical fission reaction can be represented in words in the following manner:

Neutron + Fissionable nucleus —> Fission-product nuclei + Neutrons + Beta electrons + Gamma photons.

For the purposes of this discussion, a fissionable isotope will be one in which the fission reaction can be caused by neutrons.

In the design of power reactors, the process of central importance is the **chain reaction**. The possibility of using nuclear fission to produce power in a reactor arises from the fact that 2.5 neutrons are emitted, on average, in each uranium–235 fission process. Plutonium–239 fission releases three neutrons on average per fission process. The reaction becomes self-sustaining if at least one neutron can be captured by another atom, leading to another fissioning and the maintenance of the chain reaction.

B. Elements of Reactor Design and Use

A nuclear **reactor** is an assembly of fissionable material in which nuclear fission can be maintained as a self-supporting, controlled chain reaction. The reactor core within which this assembly is contained may be thought of as a furnace in which the fissionable material is consumed, accompanied by the regulated release of thermal energy. The first self-sustained chain reaction was achieved in a graphite-moderated natural uranium assembly at the University of Chicago on December 2, 1942. Although nuclear weapons and nuclear reactors both exploit the principle of the chain reaction for their operation, the excess reactivity of a nuclear weapon is enormous, allowing it to release a huge amount of energy in an extremely short period of time. To achieve this condition, the bomb requires a high-purity fissionable material and a trigger to force the subcritical mass elements together. A neutron injection device is employed to boost reactivity even further. A reactor cannot suffer a nuclear explosion because of the geometry of the core, the low level of enrichment of the reactor fuel (or lack of enrichment, as in CANDU), and the presence of neutron-absorbing materials such as the uranium–238 in the fuel elements.

Neutrons are expelled from fissioning atoms at high velocity. For the reaction to propagate within a nuclear reactor, the neutrons must be slowed so that they can be captured by other fissionable atoms. The function of the **moderator** is to slow "fast" neutrons without absorbing them (that is, the moderator must have a "low neutron-capture cross section"). When the neutrons are slowed to near-thermal kinetic energies, the neutron-capture cross section of the fissionable material becomes much larger and a chain reaction can then be sustained by the "slow" neutrons. (1) The best moderator is "heavy hydrogen" or deuterium – an isotope of hydrogen with a neutron as well as a proton in its nucleus. Since hydrogen is difficult to handle in its elemental form (recall the explosion of the German dirigible *Hindenburg* in 1937), water is usually used as the moderator, oxygen also having a small cross section. Heavy water (D_2O), regular water (H_2O) and the solids carbon (in the form of graphite) and beryllium have been the preferred moderators.

The release of energy by fission produces large quantities of heat. Therefore, a medium called a **coolant** must be circulated through the reactor core to carry the heat away. The coolant also serves as the heat transfer medium in a reactor used for electric power production, carrying the thermal energy to a heat exchanger where it is passed to circulating steam which in turn drives a turbine to generate electricity. Since the coolant passes through the reactor core, it must withstand high temperatures and radiation damage. Good coolants are water (light and heavy), certain organic liquids (particularly a class of light oils known as aromatic terphenyls), certain liquid metals (particularly sodium), and the gases carbon dioxide and helium.

---

(1) A **fissile isotope** in this context means one in which the fission process can be caused by slow or low-energy neutrons. There are only three important fissile isotopes: the naturally occurring uranium–235, and the man-made isotopes plutonium–239 and uranium–233.

The rate of nuclear fission must be precisely controlled within the reactor to maintain the chain reaction: too low a rate of fissioning causes the chain reaction to terminate; too high a rate releases more energy than the circulating coolant can carry away. If the number of fissions is increasing, the power is rising and the reactor is said to be **supercritical**. If the number of fissions is decreasing, the reactor is **subcritical**. The rate of fissioning and the power level remain constant when the reactor is just **critical**. **Reactivity** is a measure of the departure of a reactor from criticality. Positive reactivity means the neutron flux in the reactor core is increasing and the power level is rising; negative reactivity means the neutron flux is decreasing and the power level is falling.

Control rods made of a neutron-absorbing material such as cadmium are used to vary the rate of the reaction. Moving the control rods in or out of the reactor core alters the number of neutrons available to sustain the chain reaction. The control rods can be fully inserted to shut down the nuclear reaction. A reactor may also be equipped with a system to introduce a **poison** into the core. A poison is any non-fissile substance having a high capacity to capture neutrons and thereby decrease reactivity (suppress the chain reaction).

In some circumstances, such as a serious loss-of-coolant accident, normal reactor control systems may not be capable of handling the situation. For these infrequent events, additional safety systems such as **emergency core cooling** and reactor **containment** can be called upon to reduce the consequences of an accident. Emergency core cooling usually takes the form of a system designed to inject large quantities of cool water into the heat transport system following a major loss of coolant. Primary containment is the reinforced concrete structure housing the reactor and its closely related systems. Its function is to contain radioactivity if the reactor core is breached in a major accident.

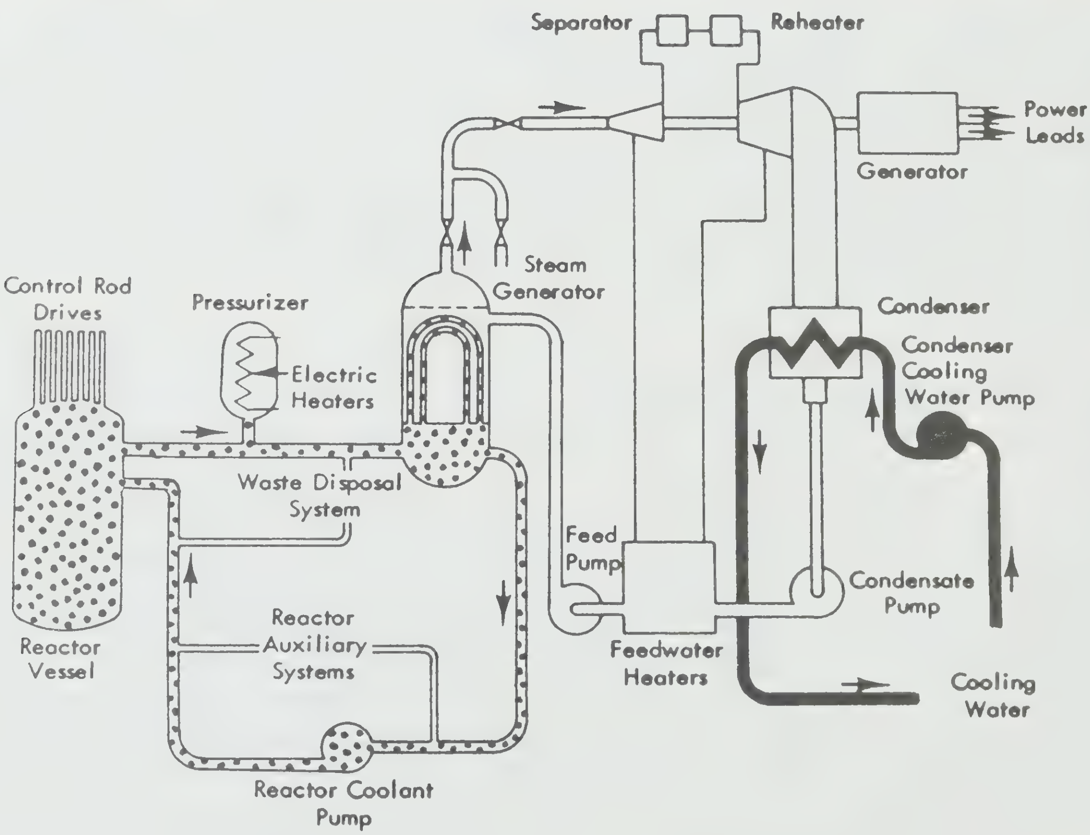
Mechanical control systems would be incapable of controlling a reactor if the fission process were only a function of the time taken for the moderator to slow fast neutrons to thermal velocities (on the order of a millisecond or 10^{-3} seconds). Most neutrons are emitted instantaneously during the fission process itself, and these are referred to as **prompt neutrons**. A small percentage (less than 1%) of the neutrons are emitted subsequently by the fission fragments after one or more beta decays and an appreciable time lag; these are referred to as **delayed neutrons**. The total number of neutrons available to sustain the fission process is the sum of the prompt and the delayed neutrons. An objective in reactor design is to be "prompt subcritical" but "overall supercritical" – that is, the prompt neutrons alone cannot sustain the chain reaction and the delayed neutrons supply the margin of criticality, allowing the mechanical controls to follow the chain reaction.

At least 45 different delayed-neutron precursor isotopes (fission fragments that subsequently decay via delayed neutron emission) are produced in a fission chain reaction. These precursors may be classified into groups with half-lives ranging from about 0.2 to 55 seconds. Their overall average half-life of approximately six seconds provides the margin for normal reactor control.

Liquid-cooled reactors exhibit either a **positive** or a **negative void reactivity coefficient**. A positive coefficient means that any event which leads to boiling of the primary coolant will cause a rise in reactivity and a surge in reactor power. CANDU reactors have a positive void reactivity coefficient and therefore their shut-down systems have to be carefully designed and computer controlled for rapid reactor shut-down. A negative coefficient, characteristic of light water reactors, means that boiling of the primary coolant will lower reactivity and depress reactor power.

About 4% of the fission energy released appears as heat generated by the decay of radioactive fission products. This decay heat continues to be produced after a reactor is shut down. Removal of decay heat during shutdown must be provided for, or the reactor core temperature will rise causing fuel element melting and failure.

Figure 2: Schematic Representation of a Pressurized Light Water Reactor



Source: Tong, L.S. and Joel Weisman, *Thermal Analysis of Pressurized Water Reactors*, Second Edition, American Nuclear Society, 1979, p. 2.

The reactor type displayed in Figure 2 is the pressurized light-water reactor, the most commonly used design abroad. A primary cooling system, operating under high pressure to keep the coolant from boiling, removes heat from the reactor core and carries it to the steam generators. A secondary cooling system operating at lower pressure extracts heat from the primary coolant and transfers steam produced in the steam generators to turbine/generator sets for generating electricity. A third cooling system uses water from an external source such as a river or lake to condense the steam leaving the turbines. In this configuration, the primary cooling system is isolated both from the external cooling water and from the turbines. Light water serves as both coolant and moderator in this design.

Three isotopes of uranium occur naturally: uranium–238 with an abundance of 99.283%, uranium–235 (0.711%) and uranium–234 (0.006%). Uranium–234 may be disregarded because of its low abundance. The importance of U–235 lies in its being the only one of several hundred naturally-occurring isotopes which is spontaneously fissionable by the capture of slow neutrons. Uranium–235 is necessarily the initial fuel for all reactor operation and, if fission power is to become a long-term contributor to society's energy needs, then breeder reactors are part of that developmental path.

Most reactors belong to one of three types: research reactors, power reactors and breeder reactors. **Research reactors** typically serve as a source of neutrons for experimental purposes. They are used to make physical and chemical measurements, to study the effects of neutrons on biological and nonbiological systems, to produce radionuclides used in medical and industrial applications, for neutron activation studies, and for investigating new reactor designs. Many low-power reactors are operating at universities and other research facilities for experimental and training purposes.

Power reactors are used to generate electricity, to produce heat for industrial and district heating applications, for ship and submarine propulsion (often referred to as "propulsion reactors" in this application), and for aerospace purposes. There are as many reactors in service in the navies of the United States, the Soviet Union, Great Britain, France and China as there are reactors generating electricity in the 26 countries of the world which have developed nuclear-electricity. The United States, West Germany and Japan each built a merchant vessel equipped with nuclear propulsion (the American *Savannah* commissioned in 1962, the German *Otto Hahn* commissioned in 1968 and the Japanese *Mutsu-Maru* commissioned in 1973), but all three were subsequently taken out of service due to doubtful profitability and the difficulty experienced in gaining permission to put into various ports. The Soviet Union has constructed a series of the world's largest and most powerful icebreakers, powered by nuclear reactors. Small reactors have been used to provide electrical power on board satellites and spacecraft. In 1978, Canada had to clean up radioactive debris from the atomic-powered Soviet Cosmos satellite which came down over the Northwest Territories. A small power reactor was formerly operated at a U.S. research station in Antarctica.

Breeder reactors convert the fertile isotopes[1] thorium–232 and uranium–238 into the (man-made) fissile isotopes uranium–233 and plutonium–239 respectively; that is, they "breed" new reactor fuels in greater quantities than the fuel they consume in their own operation. Reactors with a breeding ratio less than one but which nonetheless create significant quantities of fissile material are often referred to as "converter" reactors. CANDU is a converter reactor, creating plutonium–239 from uranium–238 during its operation. CANDU could also be made to operate as a near-breeder on a thorium fuel cycle. Reactors which create only small quantities of new fissile material are sometimes referred to as "burner" reactors. Light water reactors tend to have relatively low breeding ratios. Since breeder reactors are also employed as power reactors, we shall consider breeders to form a subset of the power reactor group.

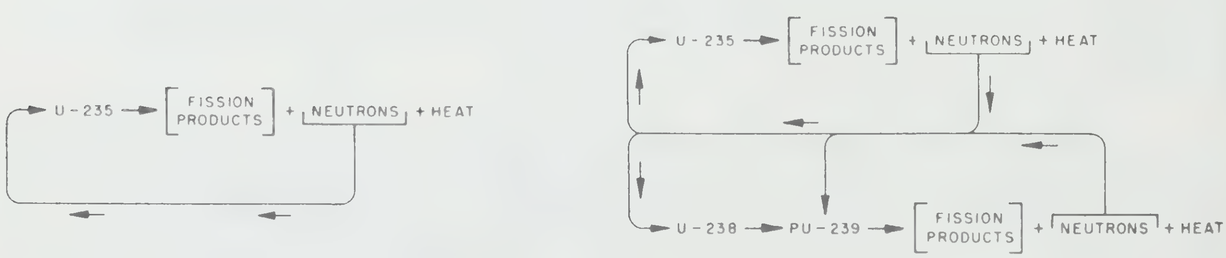
The difference between the uranium–235 fission power reaction and the uranium–238 breeder reaction is shown schematically in Figure 3.

Figure 3: Schematic Representation of the U–235 Fission Power Reaction and the U–238 Breeder Reaction

---

Schematic representation of the U–235 fission power reaction:

Schematic representation of the U–238 breeder reaction:



Source: Hubbert, M. King, "Energy Resources" in *Resources and Man*, National Academy of Sciences-National Research Council, Committee on Resources and Man, W.H. Freeman and Company, San Francisco, 1969, p. 220-221.

Most power reactors in turn belong to one of the six main types described in the following list, although there are numerous variants of these basic designs (Leclercq, 1986, p. 71).

(1) A **fertile isotope** is one capable of being converted into a fissile isotope. Uranium–238 and thorium–232, not in themselves fissionable, can be converted through the absorption of neutrons into the previously nonexistent isotopes plutonium–239 and uranium–233, respectively.

(1) **Gas-cooled reactors (GCR)** use graphite as the moderator; either natural or enriched uranium as fuel; and carbon dioxide gas as coolant. Most of the early GCRs were of the British Magnox type or the French UNGG (Uranium Naturel, Graphite Gaz) type; a more recent version deployed by the British is known as the **advanced gas-cooled reactor (AGR)**.

(2) **Heavy water reactors (HWR)** use heavy water as the moderator; natural uranium, enriched uranium or plutonium as fuel; and pressurized heavy water, carbon dioxide gas or boiling light water as coolant. Most of the reactors in this category are of the CANDU design, employing pressurized heavy water as the coolant and natural uranium as the fuel. They are known as **pressurized heavy water reactors (PHWR)**. The CANDU design itself is usually designated as CANDU–PHWR.

(3) **Pressurized water reactors (PWR)** use light water as the moderator; enriched uranium as fuel; and pressurized light water as coolant. The PWR operates at sufficiently high coolant pressures that the water is kept in the liquid state and passes to a steam generator, creating steam in a secondary system to drive a turbine. In the Soviet Union this type is known as the VVER (Vode Vodjanie Energitcheskie Reactor); in France as the REP (Réacteur à Eau sous Pression).

(4) **Boiling water reactors (BWR)** use light water as the moderator; enriched uranium as fuel; and boiling light water as coolant. The BWR operates at low coolant pressures, with steam being allowed to form in the primary cooling circuit and passing directly to a turbine. The BWR is a simpler, less costly design than the PWR because steam generators are not required, but the PWR isolates the turbine on a secondary circuit and thus radioactivity escaping from the fuel elements does not contaminate the turbine.

The term **light water reactor (LWR)** is used to refer collectively to PWRs and BWRs.

(5) **Light-water graphite reactors (LWGR)** use graphite as the moderator; enriched uranium as fuel; and boiling light water as coolant. The LWGRs are Soviet power reactors, designated as RBMK (Reactor Bolche Molchnastie Kipiache). The Chernobyl units belong to this class.

(6) **Fast breeder reactors (FBR)** have no moderator (hence the name "fast" breeder since the neutron velocities are not moderated); use enriched uranium or plutonium as fuel; and liquid sodium as coolant. The principal design type in this category has been the liquid-metal cooled, fast breeder reactor, LMFBR, based on the uranium–238/plutonium–239 cycle. With the discovery in recent years that the world's uranium–235 reserves are much larger than had been thought, the sense of urgency has disappeared from the breeder reactor program.

The United States, the Soviet Union, France and Japan have led the world in adopting the PWR type for power production. [The Soviet Union operates 23 graphite-moderated reactors of the RBMK type as well as its 29 PWRs, but the majority of the

Soviet power reactors under construction today are PWRs.] As statistics compiled in the *World Nuclear Industry Handbook 1988* (NEI, 1988, p. 10ff) reveal, the PWR represented 60% of the 308,166 million watts (308,166 megawatts or 308.2 gigawatts) in generating capacity installed in 418 reactors operable worldwide as of July 31, 1987. PWRs are even more dominant in the group of reactors under construction, where they represent 75.5% of the 118.6 gigawatts (GW) of generating capacity being built in 130 new units.

The BWR type holds second place among operable reactors with 23.5% of installed capacity, but represents only 7.4% of capacity of reactors under construction.

Another line of reactor development, main advocate of which has been the United Kingdom, is the GCR, known as the Magnox in earlier British versions and as the AGR in more recent form. ["Magnox" refers to the magnesium oxide alloy used to sheath the fuel elements.] The gas-cooled reactor design suffers from the poor performance of both older and newer units: Magnox reactors have a disappointing 57.9% capacity-weighted load factor over their operating lives (as of end-June 1987) and the newer AGRs are doing even more poorly at 34.8%. In contrast, the PWR design averages 62.7% over its lifetime and the BWR 61.4%. The GCR accounts for 5% of operable reactor capacity and only 2.2% of reactor capacity under construction.

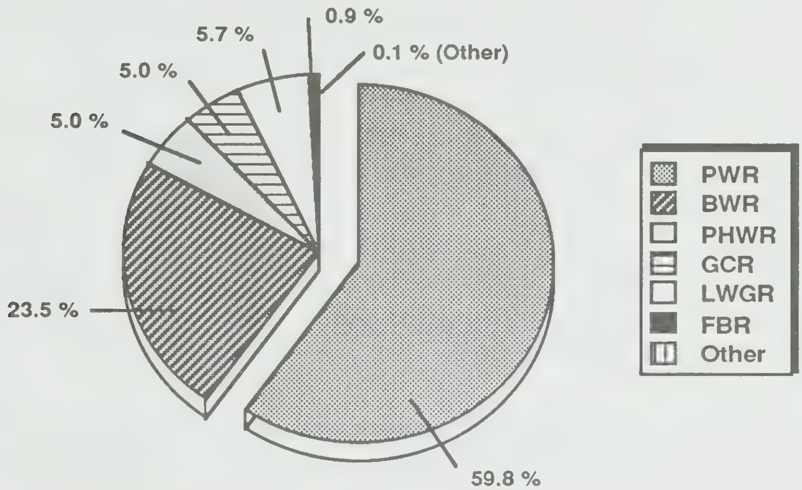
The heavy water reactor, in the PHWR variant pioneered by Canada, accounts for 5% of operable reactor capacity and 7.8% of capacity under construction. The PHWR exhibits the superior operating record, with a 75.5% capacity-weighted load factor through mid-1987. Despite its operating success, the PHWR type has achieved only limited penetration of the world reactor market when compared with the light water design. In terms of planned capacity, the PHWR accounts for just 2% of 141 GW planned in 149 units. This reflects the fact that only one new CANDU reactor was being planned by a Canadian utility when the survey was taken (and that remains to be confirmed), and only six PHWR reactors were being planned in other countries (five units in India, in which Canada has no involvement, and one unit in Turkey).

The LWGR design claims 5.7% of operable generating capacity and 5.9% of capacity under construction. The LWGR's share of reactor construction is represented entirely by six large RBMK units being built in the U.S.S.R.

The fast breeder claims only 0.9% of operable generating capacity and 1.2% of capacity under construction, but will account for a rising share of generating capacity in the future as fission power evolves.

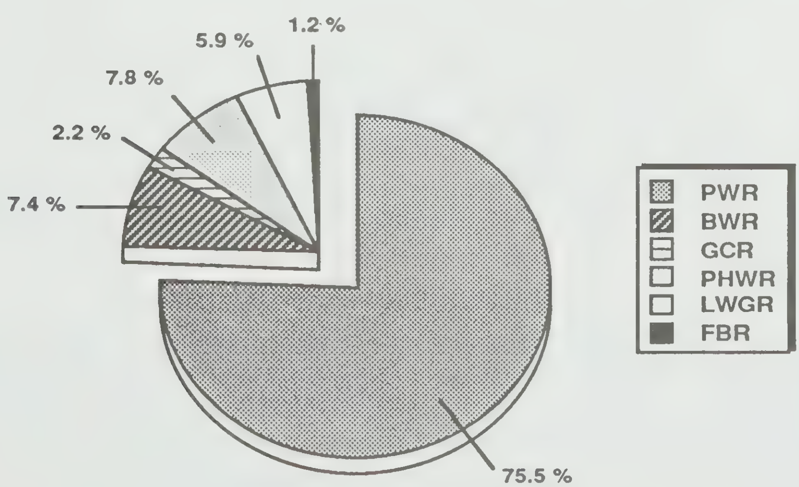
Figures 4 and 5 summarize the shares held at mid-1987 by the principal design types, for operable reactors and for reactors under construction, respectively. The dominance of the PWR design is evident.

Figure 4: Operable Reactors Worldwide at July 31, 1987, by Reactor Type



Source: Nuclear Engineering International, "Reactor Statistics", *World Nuclear Industry Handbook 1988*, Reed Business Publishing, Sutton, England, 1988, p. 10.

Figure 5: Reactors under Construction Worldwide at July 31, 1987, by Reactor Type



Source: Nuclear Engineering International, "Reactor Statistics", *World Nuclear Industry Handbook 1988*, Reed Business Publishing, Sutton, England, 1988, p. 10.

C. The CANDU System

There are two fundamental approaches to designing a reactor to sustain a chain reaction. One is to increase the concentration of fissile atoms within the fuel elements, accomplished by enriching the fuel and thereby increasing the probability of fissile capture of neutrons before their absorption in non-productive core materials. This is the approach taken in light water reactors which operate with fuel elements enriched in uranium–235 to about 3% in PWRs and up to 5% in BWRs. The other is to use natural uranium fuel (0.7% uranium–235, the isotopic abundance found in nature) and employ materials in the core which minimize neutron absorption. CANDU – an acronym for CANada-Deuterium-Uranium – denotes a distinct branch of power reactor design pioneered in Canada which adopts the latter approach. CANDU thus avoids the additional cost of developing uranium enrichment facilities (or of depending upon a foreign supplier for enriched fuel) and lessens the economic incentive to reprocess spent fuel, again avoiding an expensive step in the nuclear fuel cycle.

CANDU is heavy water moderated and cooled, to exploit the exceptionally low neutron-capture cross section of the deuterium isotope. Heavy water is an expensive commodity, however, and adds substantially to the capital cost of the CANDU reactor. There is also a heavy water make-up cost because small quantities are lost under normal operating conditions. A loss rate of less than 1% of the heavy water inventory per year has been achieved, overcoming the early fear that heavy water losses might prove to be uneconomically high. The heavy water inventory in older CANDUs is about 1 tonne per megawatt of generating capacity; in newer and larger units about 0.8 tonne per megawatt. Zirconium alloys, which absorb far fewer neutrons than steel, are used to fabricate structural components and to sheath the fuel elements, adding to the neutron economy of the CANDU design.

Given the lower power density in a CANDU reactor core, which is an aspect of using natural uranium fuel, the core is considerably larger than in other reactor types with a comparable power rating. The early CANDU designers were concerned that fabricating a pressure vessel for high-power CANDU reactors would be very difficult because of its size and instead opted for a pressure tube system to enclose the fuel bundles within the reactor core. The fuel bundles are therefore contained within a large number of individual pressure tubes which also carry the hot, pressurized heavy-water coolant. This design feature allows the coolant and moderator to be kept separate and the cool, low-pressure moderator to be enclosed within a comparatively simple vessel known as the calandria. In contrast, coolant and moderator are one in the LWR and must be contained within a large, thick-walled, complex pressure vessel. Pressure tubes are replaceable and Ontario Hydro is becoming adept at this task. It is possible that CANDU units may be able to operate for many decades, with periodic replacement of the pressure tubes and other reactor components. Reactor pressure vessels are not replaceable and impose a more restricted lifetime on other reactor designs.

The use of a pressure tube design confers a major operating advantage on CANDU: on-power refuelling. Whereas other reactors have to be shut down for

refuelling, CANDU can continue to operate at full power while remotely controlled refuelling machines move fuel bundles in and out of the core. Failed fuel elements can also be removed while the reactor continues to operate. Much of CANDU's superior operating record can be traced to on-power refuelling. The pressure tubes are horizontal so that new fuel bundles can be simply pushed into one end of the tube by a fuelling machine and spent fuel bundles taken out of the other end by another fuelling machine. With this configuration it is also possible to insert fresh fuel bundles from opposite ends of adjacent fuel channels and achieve a more uniform power distribution over the length of the reactor. Another benefit of this approach is that it allows the manufacture of short fuel bundles of simple design.

Adopting a pressure tube design has not come without its drawbacks. The much more complicated plumbing of a CANDU reactor core contributes to the higher capital cost of building this type of reactor, an important consideration in an era of high capital carrying charges and frequently delayed construction schedules. Moreover, the early hope that the pressure tube system would last for the 30-year life then attributed to the reactor has been dashed. The premature retubing first of Pickering 1 and 2 in the wake of the ruptured tube at unit 2 in 1983 and soon of Pickering 3 and 4,[1] despite the use of a more advanced zirconium-niobium alloy in the tubing, has been a costly disappointment. The direct cost of materials, labour and equipment needed to remove and replace the pressure tubes, and of recommissioning units 1 and 2, has recently been estimated by Ontario Hydro at $402 million. The cost of replacement power for the lost nuclear-electric output was about $200,000 to $250,000 per unit per day, depending upon the type of replacement energy (coal-fired generation at Ontario Hydro stations or purchased power from other utilities). (Ontario Hydro, 1987a, p. 121-122) Thus the economic penalty of having two reactors shut down for several years for retubing has been large.[2] Even so, the performance of CANDU reactors, most of which are operated by Ontario Hydro, remains impressive when compared with other designs.

> The high performance figures achieved by Ontario Hydro are particularly noteworthy. This utility still enjoys the highest lifetime [load factor] figure, and yet for four years, two of its 15 reactors have been shut down for a complete pressure tube replacement operation after a tube failure in 1983, and are only now going back into service. (Howles, 1988, p. 22)

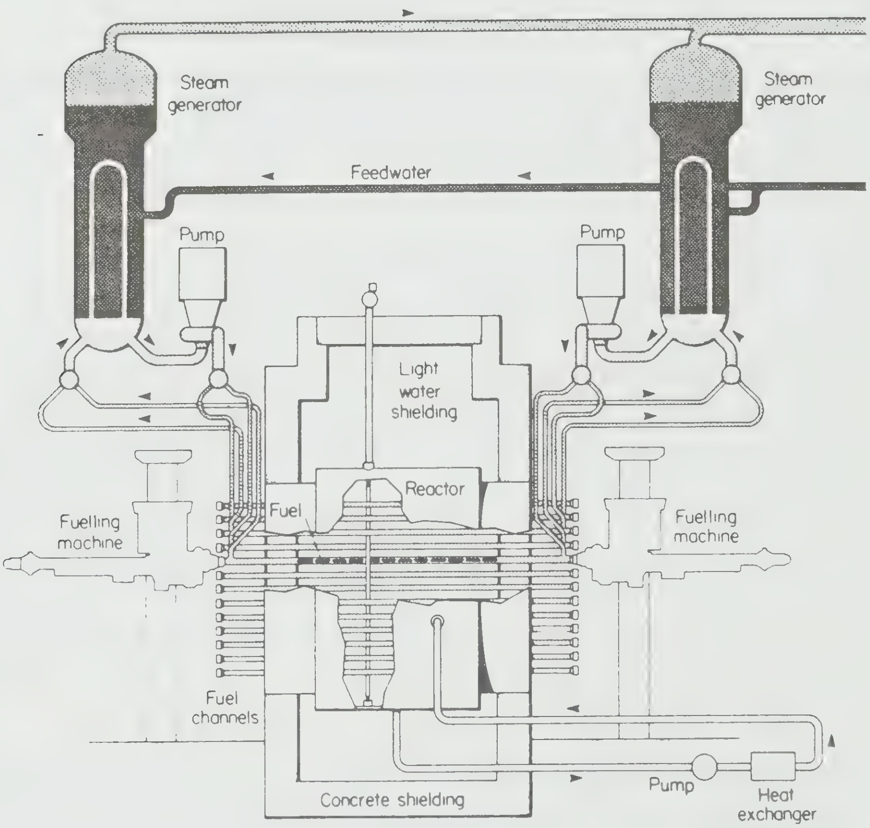
---

(1) Ontario Hydro has announced that Pickering unit 3 will be shut down for retubing in 1989 and unit 4 in 1991. Retubing of these units had been planned for the late 1990s. The utility expects retubing to take 23 months at unit 3 and 19 months at unit 4, and to cost $500 million in total. The decision was taken after Ontario Hydro discovered higher than expected absorption of deuterium in pressure tubes of both units 3 and 4. (Ontario Hydro, 1988c)

(2) The cost of retubing and of providing replacement energy is being approximately equally shared by Ontario Hydro, the Province of Ontario and AECL as the joint owners of Pickering units 1 and 2. The Nuclear Payback Agreement which applies to these two reactors is discussed in the later section on The Economics of Nuclear Power.

Figure 6 illustrates the principal features of the CANDU reactor, the primary coolant circuit and the steam generators.

Figure 6: The Principal Design Features of the CANDU Reactor System



Source: Thexton, H.E., "Canada" in *Nuclear Power: Policy and Prospects*, P.M.S. Jones (ed.), John Wiley & Sons, Toronto, 1987, p. 203.

Canada has been a leader in developing a systematic approach to minimizing risk in reactor operation. Accident prevention and mitigation through superior design, high-quality equipment and well-trained personnel is referred to as "defence-in-depth". This concern with safety is one of the legacies of the 1952 NRX reactor accident at Chalk River. Defence-in-depth assumes that reactor design will have occasional imperfections, that equipment will sometimes fail, and that reactor operators will occasionally make mistakes. The intent is to minimize the probability of an accident occurring and to minimize the consequences of an accident, should it occur.

As described by Ontario Hydro, the concept of defence-in-depth rests on five factors (Ontario Hydro, 1987a, p. 101-104).

(1) High-quality station equipment built to strict engineering specifications is the first line of defence.

(2) In the event of failure in a major reactor system, independent safety systems are activated to compensate for or offset the failure. These safety systems are designed wherever possible to incorporate certain principles of operation. **Separation** means that a failure in one location or system will not affect components in other locations or systems. **Diversity** means that there is more than one way of achieving a result or condition, such as shutting down the reactor. **Redundancy** means that more than one component is available for a given task or operation, such as connecting two pumps in parallel when only one is required. **Independence** means that systems or components operate independently of each other; one example is having independent power supplies for separate systems. **Fail-safe** means that the failure of a component or system automatically causes that component or system to assume a safe condition. For example, shut-off rods may be held above the reactor by electromagnetic clamps; a power failure causes the rods to be released and drop into the reactor, shutting it down.

CANDU reactors have two general classes of safety systems: **reactor shutdown systems** and an **emergency core cooling system** (ECCS). Every CANDU unit has two independent shutdown systems, of the three types of shutdown system that have been designed for CANDU reactors. All CANDU reactors have **shut-off rods** made of neutron-absorbing cadmium. Rapid insertion of the shut-off rods terminates the chain reaction because there are not enough neutrons available to sustain it. Some CANDU reactors are equipped with a **moderator dump**, a system which rapidly drops the moderator into a holding tank beneath the reactor. Loss of the moderator means that fast neutrons are not slowed to cause further fissioning and the chain reaction is again terminated. Other CANDU reactors have a **poison injection** system, in which a liquid with neutron-absorbing properties can be injected under pressure into the moderator. The injected liquid absorbs large numbers of neutrons and "poisons" the chain reaction.

The ECCS is activated if cooling of the reactor core fails, as in a major break in the primary cooling system. Water stored in a reservoir is injected under pressure through the emergency cooling system to flow over the fuel and carry away the heat.

(3) The third factor is barriers designed to contain or to minimize any release of radioactivity. The philosophy has been to create a series of physical barriers to the release of radioactivity during either normal operation or an emergency. The first barrier is the fuel itself which, barring failure of the fuel pellet, will contain 99% of the radioactivity created during normal reactor operation. CANDU fuel is fabricated

as ceramic pellets of uranium dioxide (UO_2) with a melting point of 2800°C. Fuel pellets are in turn contained within sealed zircaloy metal tubes, constituting another barrier to the escape of radioactivity. The fuel bundles are located in pressure tubes within the closed, primary cooling system. The reactor and its main supporting systems are housed within a thick-walled concrete building and, in the case of multi-unit Ontario Hydro stations, connected to a vacuum building by a large duct with pressure-relief valves. If a major break occurs in the primary cooling system, escaping coolant will rapidly form steam and cause the pressure-relief valves to open. The vacuum building is maintained at about one-tenth of atmospheric pressure and the radioactive steam is sucked into it. A dousing system in the vacuum building will condense the steam, minimizing leakage of radioactivity from the containment system to the environment. The final barrier is a one-kilometre exclusion zone at the plant boundary which provides for some dilution before escaping radioactivity reaches any residential area.

(4) A particularly important factor is operator training. As reactor accidents in the past have shown, serious events almost invariably have a substantial or even dominant component of operator error. Ontario Hydro personnel receive at least eight years of training and must pass a series of examinations set by the utility and by the AECB before being licensed as reactor operators.

(5) The final factor is fault detection and correction. A continuous program of testing and inspection, coupled with automatic fault detection systems, is used to ensure the reactor is operating properly and to correct faults that are detected.

Not all reactor accidents are anticipated or are accorded the correct probability of occurrence before the fact. For example, it had been thought that a pressure tube failure in a CANDU reactor would be signalled first by a leaking condition, the so-called "leak-before-break" assumption. In the event, the failure of the pressure tube at Pickering 2 was abrupt – the tube ruptured with no warning of impending failure. Nonetheless, operators responded correctly and reactor operation was stopped with the normal shutdown system (no recourse to emergency systems was needed) in the most serious accident yet in a CANDU reactor. The Pickering 2 pressure tube failure, despite its economic consequences, demonstrated the ability of the CANDU system to cope with a major loss-of-coolant accident.

The CANDU reactor requires substantial amounts of heavy water (deuterium oxide, D_2O) for use both as moderator and coolant. Canada has invested heavily in heavy water production facilities in a program that first suffered from an insufficient supply of heavy water and later from too much as reactor sales failed to materialize.

The heavy water production process is based on the behaviour of deuterium in a mixture of water and hydrogen sulphide. When liquid water and gaseous hydrogen sulphide are mixed, deuterium atoms will move freely between the liquid and the gas – toward the gas at higher temperature and toward the liquid at lower temperature. The

first and second stages of a heavy water plant consist of exchange towers operated with a cold (32°C) top section and a hot (128°C) bottom section. Hydrogen sulphide gas circulates upward through the tower and water circulates downward, with mixing promoted by a series of perforated trays. The result is an enrichment of deuterium in the central section of the tower.

Hydrogen sulphide gas enriched in deuterium is extracted from the central section of the first tower in the train and passes to the second tower for the next stage of enrichment. The first stage enriches the hydrogen sulphide gas from 0.015% deuterium to 0.07%; the second stage to about 0.35%. A third stage of enrichment yields a product containing 10-30% heavy water. The final step is a distillation process to finish the output to "reactor grade" heavy water with a purity of 99.75% deuterium oxide. The heavy water production process requires that very large volumes of water be treated: approximately 340,000 tonnes for every tonne of heavy water extracted. (Ontario Hydro, *Heavy Water*, undated)

The cost of operating a heavy water plant is largely insensitive to the rate of production; that is, very little saving is achieved by running the plant at less than full capacity. Thus the unit cost of producing heavy water rises sharply as throughput falls. Information on Ontario Hydro's cost of heavy water production and on the federal investment in Canadian heavy water development is provided in the section on The Economics of Nuclear Power.

Safety is a central concern at heavy water plants because hydrogen sulphide is a colourless, toxic gas that is slightly heavier than air. Plant personnel and nearby communities must be protected from dangerous concentrations of this gas.

AECL has dismantled its Glace Bay and Port Hawkesbury heavy water plants in Nova Scotia. Of the four 800 tonnes/year heavy water plants planned by Ontario Hydro at the Bruce site, only Bruce Heavy Water Plant (HWP) B is operating. Each Darlington reactor will require about one year's output from Bruce HWP B for its initial charge of heavy water. Bruce HWP A and D are mothballed; unit C was not constructed. The 800 tonnes/year LaPrade HWP at Gentilly is also mothballed. AECL is carrying a costly inventory of unsold heavy water that it attempts to market in competition with Ontario Hydro.

Table 1 summarizes the major differences between the CANDU pressurized heavy-water reactor system (CANDU–PHWR) and the pressurized light-water reactor system (PWR).

Table 1: Differences Between the CANDU–PHWR and the PWR

CANDU–PHWR	PWR
• Natural uranium fuel (0.7% U–235)	• Enriched uranium fuel (1-3% U–235)
• D_2O cooled and moderated	• H_2O cooled and moderated
• On-power refuelling – higher load capacity factor – higher fuel burn-up – on-power failed fuel removal	• Batch refuelling during shut-down
• Pressure tubes	• Pressure vessel
• Larger core size with lower power density	• Smaller core size with higher power density
• Comparatively higher capital cost	• Comparatively higher operating cost
• More complicated plumbing	• Less complicated plumbing
• Vacuum building at multi-unit stations	• Various pressure suppression methods
• Higher leak-rate containment	• Lower leak-rate containment
• Positive void reactivity coefficient	• Negative void reactivity coefficient
• Relatively high tritium and carbon–14 production and emissions	• Low tritium and carbon–14 production and emissions
• Shared containment at Ontario Hydro stations	• Separate containment systems
• Easily adapted to thorium fuel cycle	• Not applicable

Canadian Nuclear Development

A. The Power Reactor Program

Heavy water, D_2O, was discovered in 1930 and its properties as a neutron moderator were soon recognized. Heavy water became a strategic commodity during World War II, as both the Allies and the Third Reich laboured to produce the atomic bomb. France had bought up world stocks of heavy water on the eve of the war and some of these stocks were transferred first to England and then to Canada, where Canadian and British research teams worked to construct the first heavy-water-moderated reactor. In the meantime, Allied sabotage prevented the Germans from getting enough heavy water from the world's only production plant in Norway to continue their nuclear research efforts using D_2O.

Canada's first nuclear reactor was ZEEP – the Zero Energy Experimental Pile. ZEEP was built in Chalk River in eastern Ontario, and became the first functional reactor outside of the United States with its startup in September of 1945. Its purpose was to confirm design parameters for a larger reactor and to perform tests on a heavy-water moderated reactor system. (Thexton, 1987)

ZEEP was followed by the 20 thermal-megawatt (MWt) NRX (Nuclear Research Experimental) reactor which began operation at Chalk River in 1947. This heavy-water-moderated research reactor was intended to be a plutonium production unit but proved to be an excellent test bed for nuclear fuels and materials research, because of its large size and high neutron flux. In December 1952, the NRX reactor was badly damaged in an accident caused by operating errors combined with mechanical defects in shut-off rods. NRX had no independent fast shut-down system and no containment system. Before the chain reaction could be stopped by dumping the moderator, extensive damage to structural components and fuel elements occurred, causing the release of radioactivity. It took 14 months to rehabilitate the reactor, which re-entered service at an upgraded rating of 40 MWt. The NRX accident, Canada's first and most serious nuclear mishap, had a major influence on the safety engineering of later power reactors. (Thexton, 1987; Ontario, Nuclear Safety Review, 1988d, p. 42)

The 200 MWt NRU (National Research Universal) research reactor began operation in 1957 at Chalk River. The reactor's vertical core was loaded at the top, using a 240-ton transfer flask which allowed on-power refuelling. In May 1958, a fuel rod broke apart during unloading of the reactor and the resulting contamination caused it to be shut down for six months. Unlike NRX which was largely designed by British scientists working at Chalk River, NRU was a Canadian-designed, heavy-water-moderated reactor. NRX and NRU attracted researchers from several countries. A fortuitous aspect of this collaboration was Canada's early access to the use of a new zirconium alloy, zircaloy, developed by Westinghouse for the U.S. nuclear submarine

program. Zirconium alloys were to make possible the construction of a pressure tube reactor. (Thexton, 1987; Bothwell, 1988)

The next step was construction of a prototype power reactor. AECL, Ontario Hydro and Canadian General Electric joined forces to design and build the 22 MWe (net) [1] NPD (Nuclear Power Demonstration) unit at Rolphton, Ontario, near Chalk River. NPD was owned by AECL and operated by Ontario Hydro. This reactor entered service in 1962 and operated until 1987. It is now undergoing decommissioning. NPD was designed as a pressure vessel reactor with a vertical core, although Canadian engineers were worried that it would prove impracticable to build a pressure vessel large enough to contain the core of a commercially-sized, heavy-water-moderated reactor. The vessel had already been ordered from Babcock & Wilcox in Scotland when zircaloy became available and the design of a pressure tube reactor became feasible. Work stopped on the pressure vessel design and NPD was re-engineered as a pressure tube reactor. NPD also served as the model for the 125 MWe (net) KANUPP station near Karachi, Pakistan. (Thexton, 1987; Bothwell, 1988; Ontario, Nuclear Safety Review, 1988a)

Ontario Hydro and AECL next collaborated in scaling up the NPD design, constructing the 206 MWe (net) Douglas Point demonstration reactor on the east shore of Lake Huron, north of Kincardine. This site was later to become the location of the eight-unit Bruce Nuclear Generating Station. The decision to build was made in 1959 and the target date for start-up was 1964. Douglas Point was in fact not commissioned until 1967, but Ontario Hydro was sufficiently confident in the design that it began work on the multi-unit Pickering A station before Douglas Point entered service. This reactor also aided Canada in reactor export, serving as the model for the 203 MWe (net) RAPP–1 and –2 units, committed in 1963 at Rajasthan, India.

Because of a shortage in the Canadian supply of heavy water, Douglas Point was taken out of service from April to December of 1972, when its inventory of D_2O was used for Pickering reactor commissioning. The Douglas Point reactor operated until May 1984 at which time its owner, AECL, offered the unit for sale to the operator, Ontario Hydro. Hydro decided that the reactor's small size, its need for pressure tube replacement, and the lack of adequate transmission capacity from the Bruce site made continued operation uneconomic. AECL then put the reactor into a permanent shutdown condition in January 1985. Douglas Point became the first CANDU–PHWR to be placed in a "storage with surveillance" state, a 30-year delay period to be followed by reactor dismantling and entombment. The entire inventory of irradiated fuel has been placed into concrete canisters for interim, on-site dry storage. This storage program is described in the section Radioactive Waste Management in Canada. (Canada, AECL, CANDU Operations, "The Douglas Point Story", 1984; Broad, 1986)

---

(1) Net generating capacity = gross generating capacity – station service. The net capacity represents the electricity available to the grid after the electrical demand and losses of the generating station itself have been accounted for.

A variant of the heavy-water-moderated reactor system, known as the CANDU–BLW, was built by AECL for Hydro-Québec at Gentilly on the St. Lawrence River. This 250 MWe (net), commercially-sized prototype power reactor, designated Gentilly 1, was moderated by heavy water and cooled by boiling light water. It was a back-up design to the CANDU–PHWR in case heavy water coolant losses at Douglas Point and Pickering A proved to be uneconomically high. Gentilly 1 retained the pressure tube design within a vertical core. By allowing the light water coolant to boil within the pressure tubes, reducing its mass and neutron absorption characteristics, the reactor could still operate on natural uranium fuel. The reactor control system proved to be highly complex, however, and Gentilly 1 experienced a series of design and commissioning problems. From entering service in 1972 until its removal from commercial operation in 1977, Gentilly 1 ran at full power for a total of only a few weeks. The reactor was used for training purposes until 1979, when the decision was taken to mothball the station. In 1983, AECL decided to decommission Gentilly 1. The spent fuel has been transferred to concrete canisters for interim, dry storage within the turbine building. Fortunately for the PHWR design, heavy water losses at Douglas Point and Pickering proved to be quite low and interest in the CANDU–BLW type disappeared. (Thexton, 1987; Denault and De, 1985)

Another design approach was embodied in the 40 MWt WR–1 experimental reactor constructed at the Whiteshell Nuclear Research Establishment in Manitoba. This reactor type was designated CANDU–OCR to indicate that it combined a heavy water moderator with an organically-cooled system, using a specially designed light oil as coolant. The organic liquid functioned as a more efficient heat transport medium, allowing the reactor to operate at higher coolant temperature and achieve a better thermodynamic efficiency than the standard CANDU. The organic coolant had the additional advantage of developing lower radiation levels than does heavy water during reactor operation. This experimental reactor, which ran on an enriched uranium carbide fuel, achieved full power in 1965 and operated until 1985. Although the organically cooled reactor was considered to be a promising line of development and extensive studies were conducted by AECL into the 1970s, the success of Pickering A kept interest centred on CANDU–PHWR.

Ontario Hydro began building the first of its multi-unit stations, Pickering A, on Lake Ontario east of Toronto. Four 515 MWe (net) reactors at Pickering A entered commercial service from 1971 through 1973. They were followed by four 740 MWe (net) units at Bruce A on Lake Huron (1977-79). Four 516 MWe (net) units were then added at Pickering B (1983-85) and four 756 MWe (net) reactors at Bruce B (1984-87). The Pickering and Bruce Nuclear Generating Stations rank among the largest nuclear generating complexes in the world. Four 881 MWe (net) reactors are under construction today at the new Darlington site on Lake Ontario. These units will enter service from 1989 through 1992. In 1987, Ontario derived almost half of its electricity supply from nuclear units; in 1992, with the completion of Darlington, this share will rise to almost two-thirds.

A notable feature of the larger CANDU units is their conservative design rating.

The Bruce A units have already been raised from 740 MWe to 769 MWe (or to a net capacity of 848 MW when credit is made for the process steam which these units supply to the Bruce Heavy Water Plant). The Bruce B units are being rerated to 875 MWe in net output. (Ontario Hydro, 1986b, p. 5)

AECL's next design initiative was the CANDU 600 reactor. This unit combines the best elements of the established Pickering and Bruce reactor designs and incorporates a number of technological improvements. The CANDU 600 is engineered as an individual unit with a conventional containment building, distinct from Ontario Hydro's four-unit stations which share a vacuum containment system. Quebec and New Brunswick each elected to build one of the CANDU 600 series reactors, Hydro-Québec locating its 638 MWe (net) unit at Gentilly and the New Brunswick Electric Power Commission (NBEPC) siting its 633 MWe (net) reactor at Point Lepreau on the Atlantic coast. Point Lepreau has established an exceptionally good operating record with a lifetime capacity factor of 92%.

At the time that NBEPC completed Lepreau 1, it represented about a 25% addition in generating capacity to the New Brunswick Power system. Electrical utilities don't normally add generating capacity in increments much larger than about 10% of existing system capacity, because of problems in replacing that capacity when the unit is down. New Brunswick's extensive system interties with Quebec, Nova Scotia and New England allowed it to circumvent this guideline, although not without an increased risk to the stability of the New Brunswick grid.

Three Canadian provinces have thus invested in nuclear-electric generation. Ontario will soon be home to 20 operating power reactors: the eight-unit Pickering station, the eight-unit Bruce station and the four-unit Darlington station. The Douglas Point reactor and the NPD reactor are shut down and decommissioning in Ontario. Quebec has built two units at Gentilly: the Gentilly 1 experimental boiling water reactor, now decommissioning, and the Gentilly 2 CANDU 600 reactor. New Brunswick has the one CANDU 600 unit at Point Lepreau. Since 1962, 21 power reactors have been commissioned in Canada, three of which are now being decommissioned, and four reactors are under construction. No additional reactor development is committed at this time. Table 2 summarizes Canada's domestic history of power reactor development.

The 18 operating power reactors in Ontario, Quebec and New Brunswick have a total net generating capacity of 11,971 MWe (including the uprating of the Bruce B units to 875 MWe, which is underway at the time of writing, but not including any credit for process steam supplied by the Bruce A units). The four units under construction at Darlington will add 3,524 MWe (net) of generating capacity, giving Canada a total nuclear-electric generating capacity of 15,495 MWe (net) in 1992.

For the Ontario multi-unit stations, the capacities are: (1) Pickering A Nuclear Generating Station (NGS) = 2,060 MWe; (2) Pickering B NGS = 2,064 MWe; (3) Bruce A NGS = 3,076 MWe; (4) Bruce B NGS = 3,500 MWe (upon completion of the uprating); and (5) Darlington A NGS = 3,524 MWe.

Table 2: Canada's History of Power Reactor Development

Unit	Location	Type	Capacity (MWe net)	Operator	Commercial Operation	Status
NPD	Rolphton, Ont.	PHWR	22	Ont. Hydro	1962	Shut down 1987
Douglas Point	Tiverton, Ont.	PHWR	206	Ont. Hydro	1968	Shut down 1984
Pickering 1	Pickering, Ont.	PHWR	515	Ont. Hydro	1971	Operating
Pickering 2	Pickering, Ont.	PHWR	515	Ont. Hydro	1971	Operating
Pickering 3	Pickering, Ont.	PHWR	515	Ont. Hydro	1972	Operating
Pickering 4	Pickering, Ont.	PHWR	515	Ont. Hydro	1973	Operating
Gentilly 1	Gentilly, Que.	BLW	250	Hydro-Qué.	1972	Shut down 1978
Gentilly 2	Gentilly, Que.	PHWR	638	Hydro-Qué.	1983	Operating
Bruce 1 (a)	Tiverton, Ont.	PHWR	740	Ont. Hydro	1977	Operating
Bruce 2 (a)	Tiverton, Ont.	PHWR	740	Ont. Hydro	1977	Operating
Bruce 3 (a)	Tiverton, Ont.	PHWR	740	Ont. Hydro	1978	Operating
Bruce 4 (a)	Tiverton, Ont.	PHWR	740	Ont. Hydro	1979	Operating
Pt. Lepreau	Pt. Lepreau, N.B.	PHWR	633	NBEPC	1983	Operating
Pickering 5	Pickering, Ont.	PHWR	516	Ont. Hydro	1983	Operating
Pickering 6	Pickering, Ont.	PHWR	516	Ont. Hydro	1984	Operating
Pickering 7	Pickering, Ont.	PHWR	516	Ont. Hydro	1985	Operating
Pickering 8	Pickering, Ont.	PHWR	516	Ont. Hydro	1985	Operating
Bruce 6 (b)	Tiverton, Ont.	PHWR	756	Ont. Hydro	1984	Operating
Bruce 5 (b)	Tiverton, Ont.	PHWR	756	Ont. Hydro	1985	Operating
Bruce 7 (b)	Tiverton, Ont.	PHWR	756	Ont. Hydro	1986	Operating
Bruce 8 (b)	Tiverton, Ont.	PHWR	756	Ont. Hydro	1987	Operating
Darlington 2	Darlington, Ont.	PHWR	881	Ont. Hydro	1989	Construction
Darlington 1	Darlington, Ont.	PHWR	881	Ont. Hydro	1989	Construction
Darlington 3	Darlington, Ont.	PHWR	881	Ont. Hydro	1991	Construction
Darlington 4	Darlington, Ont.	PHWR	881	Ont. Hydro	1992	Construction

(a) The Bruce A units have been rerated to 769 MWe (including credit for process steam supplied to the Bruce Heavy Water Plant, they have a net capacity of 848 MW).

(b) The Bruce B units are currently being rerated to 875 MWe.

Source: Canada, AECL, *Nuclear Sector Focus*, Corporate Public Affairs, Ottawa, September 1987, p. G-4 and G-5; Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Reactors: A Scientific and Technical Review. A Submission to the Ontario Nuclear Safety Review by Atomic Energy of Canada Limited*, Toronto, 29 February 1988, Fig. 2-2.

In Ontario in 1987, nuclear-electric generation supplied 47.5% of the electricity required to meet customer demand. Fossil-fuelled generation accounted for 23.9% and hydro-electric generation for 23.8%. Burning fossil fuels (mostly coal) last year to generate electricity caused Ontario Hydro to release about 400,000 tonnes of acid gases – sulphur dioxide and nitrogen oxides – to the atmosphere. Although Hydro's total acid gas emissions in 1987 were considerably below the peak value of 531,000 tonnes in 1982, they were nonetheless up sharply from 1986 as a result of dry weather and low water levels which depressed hydraulic generation by about 15% and caused coal consumption to be almost 50% higher than forecast for 1987. Under new and stricter provincial regulations announced in 1985, the utility must lower its acid gas emissions to a limit of 215,000 tonnes in 1994. (Ontario Hydro, 1988a)

Nuclear generation plays a major part in reducing acid gas emissions in Ontario. Nuclear power displaced about two-thirds of the acid gases that Ontario Hydro would otherwise have released to the atmosphere in 1987 by burning coal instead; total acid gas emissions within Ontario were reduced by approximately one-quarter.

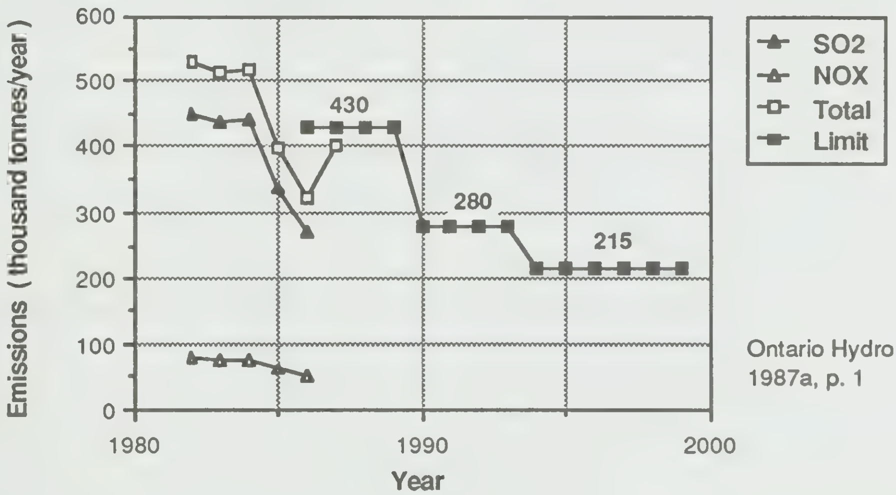
After many years of international development in which reactor size grew more or less continuously, it was recognized by AECL that there is also a need for a smaller unit. Smaller units carry a lower total price tag (although a higher cost per megawatt of installed capacity), thereby representing less of a financial burden and risk. Such units can more readily be accommodated in the systems of smaller utilities. The product of this approach by AECL to reactor evolution is the CANDU 300, design of which will soon be completed. Smaller utility systems, particularly in the developing countries, are seen as the market for CANDU 300.

AECL has simplified the CANDU 300 design in comparison with earlier CANDUs. For example, the use of data highways and multiplexers in the CANDU 300 control systems reduces instrumentation wiring by 80% relative to the CANDU 600. Whereas CANDU 600 (which will have a nominal net power output of 750 MW in new stations) has four steam generators and four primary coolant pumps, the 300 (with its nominal net power output of 450 MW) has two steam generators and two main coolant pumps. CANDU 300 will use one refuelling machine instead of the two built into the 600. Key components such as steam generators, coolant pumps, pressure tubes and fuelling machines will be identical to those already proven in service at operating CANDU stations. (Brooks and Hart, 1988; Canada, AECL, CANDU Operations, undated)

AECL is responding to a global trend confirmed in a 1985 study by the International Atomic Energy Agency (IAEA). The IAEA found that additions to generating capacity in the non-Communist world, over the 5-year period 1985-89, would most commonly be coal-fired units approximately 400 MW in size. This is the market targetted by the CANDU 300, with its nominal net output of 450 MWe. In terms of generating capacity, the IAEA review indicated that 39.3% of the additional capacity would be nuclear-electric, 38.6% would be coal-fired, 6.4% would be oil-fired and 6.3% would be hydro-electric. (Brooks and Hart, 1988)

Ontario Hydro and Acid Gas Emissions

Ontario Hydro estimates that its coal-fired stations account for about 20% of Ontario's total acid gas emissions – sulphur dioxide (SO_2) and nitrogen oxides (NO_x) – or 1% of total North American emissions. The chart shows Ontario Hydro emissions for 1982-86 and the emission limits being applied by the Province of Ontario to the utility (430,000 tonnes of total acid gas emissions for 1986-89; 280,000 tonnes for 1990-93; and 215,000 tonnes from 1994 on).



Ontario Hydro 1987a, p. 1

To decrease emissions, Ontario Hydro has: increased nuclear generation; reduced the sulphur content of the coal burned; bought hydro-electricity from Quebec and Manitoba; and tested low-NO_x burners. Each Pickering reactor displaces about 50,000 tonnes/year of acid gas emissions and each Bruce unit about 75,000 tonnes/year. Each new Darlington reactor will avoid about 90,000 tonnes/year. Without Pickering and Bruce, Hydro's acid gas emissions would be three times current levels. Blending low-sulphur Western Canadian coal with higher-sulphur U.S. coal avoids about 90,000 tonnes of emissions annually but costs Hydro an extra $60 million per year. Washing most of its purchased U.S. coal reduces the sulphur content of the coal by roughly 20%. Low-NO_x burner nozzles tested at the coal-fired Nanticoke station appear to reduce emissions of nitrogen oxides by about 35%. (Ontario Hydro, 1987a, p. 2-3)

These strategies will not, however, meet the tougher 1994 limit as the demand for electricity increases. Ontario Hydro announced in February 1988 that it is seeking government approval to install "scrubbers" (flue gas desulphurization units) at its three largest coal-fired generating stations. The 2,286 MW Lakeview, the 4,336 MW Nanticoke and the 2,100 MW Lambton Generating Stations collectively account for more than 90% of Hydro's coal-fired generation. Four different technologies for flue gas desulphurization have been assessed and the merits of each described in an environmental assessment submitted by Hydro to Environment Minister James Bradley. The scrubbers would be installed in pairs to serve each generating unit and would cost approximately $220 million (1987 dollars) per pair. Ontario Hydro may have to retrofit as many as eight 500 MW coal-fired generating units at the three stations between 1994 and 2000. Each pair of scrubbers will cost up to $12 million to operate per year and a permanent staff of between 50 and 120 people will be needed at each station to operate and maintain the scrubbers. (Ontario Hydro, 1988b)

To reduce the capital cost of the CANDU 300, AECL has worked out a 35-month construction schedule – from first concrete poured to full power operation – for the first unit on a site and a schedule as short as 30 months for subsequent units. This is expected to be achieved through a modular design which limits the weight of individual modules to about 300 tonnes (within the capacity of a very-heavy-lift crane) and by employing advanced construction techniques.

AECL has been trying to obtain a domestic sale of a CANDU 300 to NBEPC, to demonstrate the viability of the design. Although negotiations are continuing, AECL has to date been unable to obtain a commitment from NBEPC to build a CANDU 300. New Brunswick Power encountered serious financial difficulty in building Lepreau 1, which was both late coming into service and suffered a huge cost overrun, and has publicly stated that it will only consider the CANDU 300 if the federal government covers the additional capital cost and carrying charges which would arise in adding such a unit to its system rather than a 400 megawatt coal-fired unit. The utility claims that the additional capital cost, including carrying charges over the amortization period, amounts to approximately $1 billion.

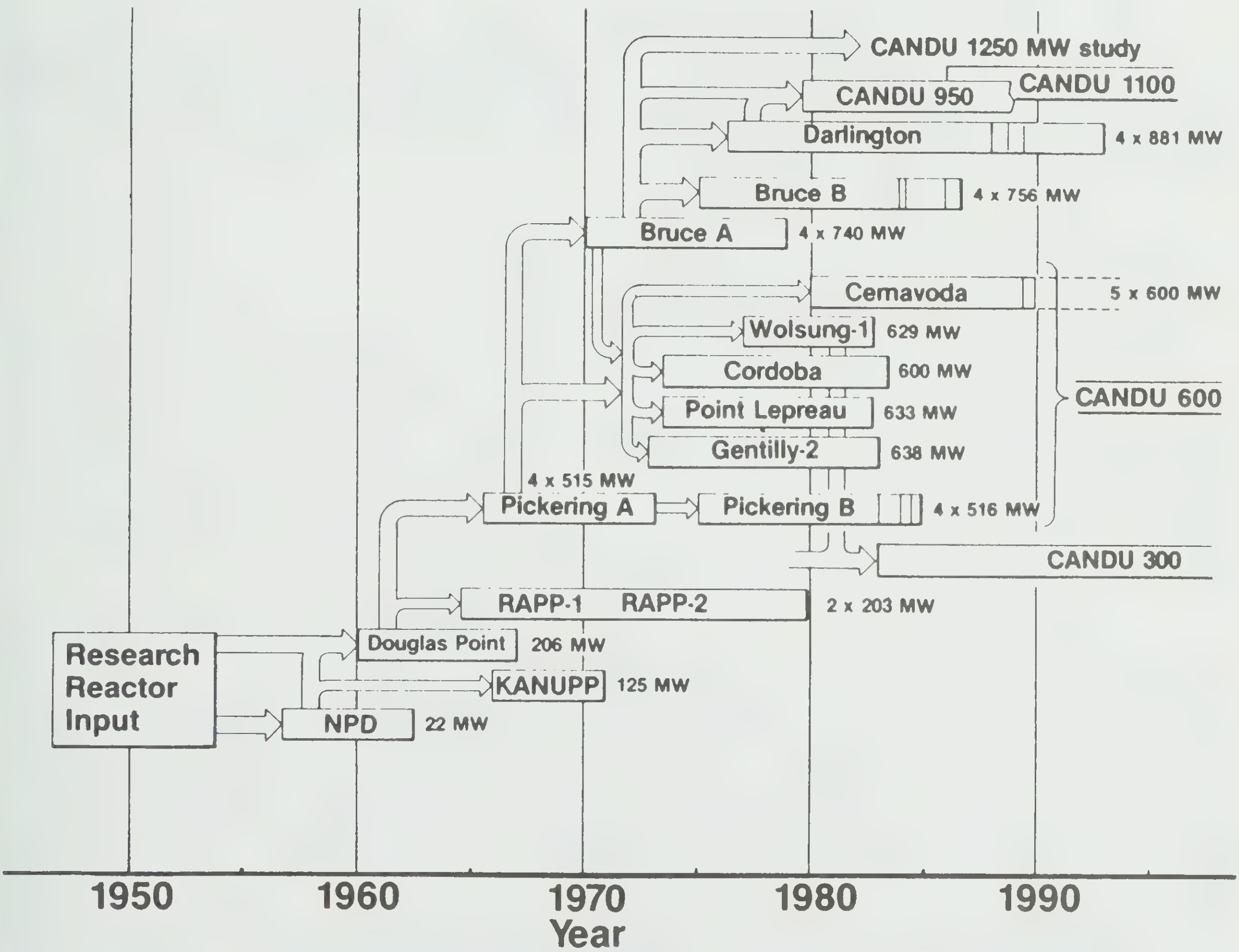
The Committee would like to see an agreement reached, although not at a cost of a billion dollars to the federal treasury. If a mutually agreeable arrangement can be established, perhaps with AECL holding a minority interest in a second Lepreau unit as it does in Pickering 1 and 2, then committing a CANDU 300 for the NBEPC system should be an important step to marketing this reactor type abroad.

Figure 7 outlines the genealogy of the CANDU design, beginning with the prototype NPD reactor and carrying through to the study of a 1,250 MW CANDU unit.

A number of CANDU units have been built in other countries. The sequence of design began with the 125 MWe (net) Kanupp unit built near Karachi, Pakistan. This reactor went on power in 1971. Two 203 MWe (net) units, Rapp–1 and Rapp–2, followed near Delhi in India. Rapp–1 entered service in 1972; Rapp–2 not until 1980. This delay reflects Canada's termination of nuclear cooperation with India after it detonated a nuclear device in May of 1974. Although cut off from Canadian nuclear assistance, India continued to build the CANDU–PHWR system on its own. Since Canada ended its nuclear cooperation, India has also completed the Mapp 1 and 2 and the Narora 1 and 2 units, all similar in output to the Rapp units (and to Douglas Point from which these reactors are derived).

AECL has been successful in selling a series of the CANDU 600 reactors abroad. Two of these units are already operating: the 600 MWe Cordoba unit at Embalse in Argentina and the 629 MWe Wolsung unit in South Korea. Five CANDU 600 units are being built in Romania, Cernavoda units 1–5. The Romanian program is falling behind schedule because of that country's insistence on domestic content. Romanian manufacturing has been unable to fabricate nuclear components of consistently high quality and the rejection rate has been excessive.

Figure 7: The Development Sequence of the CANDU Reactor System



Source: Meneley, Daniel A., "Ontario Hydro's CANDU Nuclear Stations: An Outline of Safety-related Design Aspects" in Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review. Vol. 2 Appendices*, Appendix I, Toronto, 29 February 1988, p. I/2.

A manpower problem is developing largely unremarked in the Canadian nuclear program. There is a growing shortage of professional and technical personnel in the nuclear field – Ontario Hydro, AECL and industry are all experiencing increasing difficulty in staffing. Highly trained personnel sense a loss of purpose in the nuclear program and see dwindling opportunities for advancement as the power program contracts; some are already leaving the field for employment elsewhere. Added to this

is the normal attrition in the workforce through retirement and career changes. Canadian universities and technical schools are not producing the next generation of professional and technical people in the numbers required to maintain the nuclear program in its present form. Once again, Canada is facing the prospect of importing this expertise, as it did in the early years of domestic nuclear development.

Temporarily masking this manpower situation is the recently completed management study by Cresap, a New York consulting firm, that concluded 10% of Ontario Hydro's employees were redundant, and should be retrained and redeployed within the utility. Hydro has instituted a hiring freeze while studies continue on improving productivity.

B. The Regulatory Regime and Nuclear Liability

Licensing the Canadian nuclear industry is the responsibility of the Atomic Energy Control Board (AECB), established in 1946 by the *Atomic Energy Control Act* and headquartered in Ottawa. The AECB licenses power reactors, research reactors, particle accelerators, uranium mine/mill facilities, uranium refining and fuel fabrication facilities, heavy water plants and radioactive waste management facilities. Two advisory groups – the Advisory Committee on Radiological Protection and the Advisory Committee on Nuclear Safety – assist the AECB in its work.

The AECB issues two types of licences: (1) prescribed substances licences, of which there were 47 in effect at 31 March 1988; and (2) radioisotope licences, of which there were 4,858 in effect. Prescribed substance licensing covers uranium, thorium and heavy water. Radioisotope licences are distributed by type of user as shown in Table 3. Ontario users hold the largest number of radioisotope licences (2,136), followed by Quebec (1,060), Alberta (589) and British Columbia (452). (Canada, AECB, 1988)

During fiscal year 1987-88, the AECB conducted 2,800 inspections of radioisotope users to verify compliance with *Atomic Energy Control Act* Regulations and licence conditions. Thus many licence holders are inspected less frequently than yearly. Devices such as smoke detectors are exempt from licensing because the quantity of radioactivity is very small and the detector is desgned to contain it safely.

The AECB is also responsible for administering the *Nuclear Liability Act* of 1970. The Board designates nuclear installations and, with the approval of Treasury Board, prescribes the amount of basic public liability insurance to be maintained by the operator of each facility. This coverage is intended to meet claims by the public in the event of a nuclear accident – it cannot be used to repair the operator's damaged facilities. The Nuclear Insurance Association of Canada (NIAC), a consortium of insurance companies licensed to do business in Canada, is the only approved commercial source from which the operator of a designated nuclear facility can obtain liability insurance.

Table 3: Radioisotope Licences in Effect in Canada by Type of User on 31 March 1988

Type of User	Number of Licences
Hospitals and other medical institutions	732
Universities and other educational institutions	328
Governments	557
Commercial	
Oil well logging	101
Radiography	190
Gauging	1,428
Static eliminators	775
Suppliers	209
Others	538
Total number of radioisotope licences	**4,858**

Source: Canada, AECB, *Annual Report 1987-88*, Ottawa, 1988, p. 6.

The cost to the operator of annual insurance premiums depends upon such factors as population density and land values in the vicinity of each facility. No accidents at Canada's power reactors have occurred which have had an adverse effect on the public and consequently no claims have been made against any of the three utilities operating power reactors. Table 4 indicates the basic insurance coverage for each designated nuclear installation in Canada.

In 1986, Ontario Hydro paid $1.733 million in premiums to provide the liability coverage for its power reactors. In 1987, the premiums totalled $1.7 million, reflecting the return of the Douglas Point reactor to AECL in October of 1986. The 1987 premiums were distributed as follows (Ontario Hydro, 1987a, p. 96):

Pickering A and B Generating Station –	$1,064,000
Bruce A and B Generating Stations –	$603,000
NPD Generating Station (recovered from AECL) –	$33,000

Table 4: Basic Liability Insurance Coverage on Canadian Nuclear Facilities, as of 31 March 1988

Installation	Basic Insurance
Bruce A Generating Station (4 units)	$75.0 million
Bruce B Generating Station (4 units)	$75.0 million
Gentilly 2 Nuclear Power Station (1 unit)	$75.0 million
NPD Generating Station (1 unit)	$23.4 million
Pickering A and B Generating Stations (8 units)	$75.0 million
Point Lepreau Generating Station (1 unit)	$75.0 million
University of Alberta SLOWPOKE Reactor	$0.5 million
Dalhousie University SLOWPOKE Reactor	$0.5 million
McMaster University Research Reactor	$1.5 million
École polytechnique SLOWPOKE Reactor	$0.5 million
Saskatchewan Research Council SLOWPOKE Reactor	$0.5 million
University of Toronto SLOWPOKE Reactor	$0.5 million
Eldorado Resources Limited Port Hope Refinery	$4.0 million
Zircatec Precision Industries Inc. Port Hope Fuel Fabrication Plant	$2.0 million

Note: In the case of power reactors, a nuclear facility is considered to include all of the reactors sharing a containment system. Thus Lepreau 1 is one facility, as are the eight reactors at Pickering which are all connected to one common containment system. Bruce consists of two facilities for the purposes of the Act since each set of four units shares a containment system.

Source: Canada, AECB, *Annual Report 1987-88*, Ottawa, 1988, p. 24.

NIAC does not provide all of the insurance coverage for nuclear facilities that is required under the Act and the federal government therefore maintains a Nuclear Liability Reinsurance Account, forming part of the Consolidated Revenue Fund. As of 31 March 1988, the supplementary insurance coverage provided by the Government of Canada under the *Nuclear Liability Act* is $641.6 million. This reinsurance extends the coverage on each nuclear facility to $75 million as required by the Act (thus a SLOWPOKE research reactor or a fuel fabrication plant is covered to the limit of $75 million by the federal reinsurance). The federal reinsurance coverage also includes

risks which have been excluded by NIAC as the principal insurer. NIAC will not cover damages arising from normal operating emissions at nuclear facilities, and will not insure the difference between bodily injury and personal injury (which means that claims for mental or psychological injury are excluded from NIAC coverage). The Government of Canada assumes these risks through its supplementary coverage. (Personal communication: Bob Blackburn, AECB, 11 July 1988) There have been no claims to date against the Nuclear Liability Reinsurance Account.

In the event of a nuclear accident in which public liability claims are expected to exceed the prescribed limits, the *Nuclear Liability Act* specifies that a Nuclear Damage Claims Commission be established to settle all claims arising from the accident. If the settlements exceed the liability coverage, Parliament must authorize any additional payments. Under Canadian law, all liability claims are directed at the operator of the facility. Neither the public nor the operator may sue a supplier for liability arising from a nuclear accident (although an operator can sue a supplier on other grounds). The claimant must prove that damage or injury was caused by the nuclear accident at the operator's facility. This is not necessarily a straightforward matter, since radiation-induced cancers may not appear until 20 or 30 years after exposure (there is a 10-year time limit in the Act for applying for compensation) and it may be difficult or impossible to establish cause and effect.

In April 1987, Energy Probe launched a legal challenge to the *Nuclear Liability Act* in the Ontario Supreme Court, arguing that the Act violates certain provisions of the *Canadian Charter of Rights and Freedoms*. Specifically, Energy Probe claimed that the time allowed under the Act for an individual to bring an action is unreasonably short; that the Act limits the total amount of compensation available to individuals suffering personal injury or property damage; that the Act shields nuclear suppliers and designers of equipment and products from any liability caused by a nuclear accident for which they may be responsible due to neglect or willful wrongdoing; and the Act removes the threat of greater liability as an incentive for suppliers and operators to reduce the risk of occurrence of nuclear accidents. In September 1987, an Ontario Supreme Court judge ruled that the court action was premature and based on a hypothetical argument, and that Energy Probe lacked the status required to pursue the action. Energy Probe has in turn appealed the case to the Court of Appeal of the Supreme Court of Ontario, where the matter awaits resolution. (Ontario Hydro, 1987a)

The Committee also has concerns about the provision of nuclear liability insurance in Canada, and has concluded that the current coverage is inadequate. In view of the claims arising from the Three Mile Island reactor accident (for which the Committee has been advised that liability claims now exceed $US 1 billion) and the Chernobyl accident (for which reports suggest damages approaching $US 3 billion), a maximum liability in Canada of $75 million does not accord with experience in dealing with such events. West Germany, which has never had a serious accident in its nuclear power program, has a limit on operator (utility) liability approximately ten times that of Canada. In the United States, a shared total liability carried by the operators of all American power reactors under the *Price-Anderson Act* will be raised to about $US 7

billion, once Congress renews the Act (which expired in August 1987). Each reactor operator will be liable for an amount of up to $US 60-63 million per reactor, to be paid in annual post-accident installments of $US 10-12 million into a compensation fund following an accident causing public harm (the amounts depending on the version of the bill adopted). Private insurance covers the first $US 160 million of public liability.

The Committee is not prepared to recommend what the increased level of Canadian public liability should be for operators of designated nuclear facilities, beyond observing that current limits are inadequate. The Committee was advised that an Interdepartmental Working Group has completed a review of the *Nuclear Liability Act*, including the adequacy of the prescribed insurance levels, and will be reporting its findings soon to the President of the AECB. The Committee hopes that the result of this review will be a greater degree of financial protection for the public, in the unlikely event of a serious accident at a Canadian facility.

Among its other responsibilities, the Atomic Energy Control Board ensures that Canada adheres to international protocols on nuclear safeguards. Canada is a signatory of the *Treaty on the Non-Proliferation of Nuclear Weapons* (usually referred to as the Non-Proliferation Treaty or NPT) and as such is a party to a safeguards agreement with the International Atomic Energy Agency. AECB, jointly with AECL, administers the Canadian Safeguards Support Program which assists the IAEA in improving safeguards approaches and techniques. Recent work under this Program has concentrated on improving the reliability of safeguards equipment installed at the four CANDU 600 reactors and completing the development of other safeguards equipment for these reactors. (Canada, AECB, 1988)

The Committee is disturbed, however, by reports from various quarters that the Atomic Energy Control Board lacks the financial and manpower resources to discharge its responsibilities fully. The AECB, appearing before this Committee in regard to its 1988-89 Main Estimates, stated that it needs a 50% larger budget if it is to fully carry out its present set of responsibilities. [About five years would be required for the AECB to absorb an increase in funding and related staffing of this size.] The AECB has fallen behind on its nuclear safeguard commitments to the IAEA because it lacks the resources to institute the programs and install the monitoring equipment which Canada has agreed to (a problem compounded by the recent funding cuts to AECL which administers this program jointly with AECB). The AECB has been unable to perform the independent R&D which it considered appropriate in regard to the metallurgical problems encountered in the pressure tubes of certain CANDU reactors.

The Committee has also learned that staff shortages at the Board are causing licensing and other delays. AECL has requested that the AECB study the generic licensing of the CANDU 300 reactor system, an important marketing consideration for AECL. AECB has a large amount of work to do for the Darlington start-up, however, and a "paper reactor" study does not have the same priority so the CANDU 300 licensing study has not begun. In another example, the University of Sherbrooke will be applying to the AECB to build a SLOWPOKE reactor. This application will also face

delay because the Board's work on power reactor applications takes precedence.

The Committee concludes that this shortage in resources at the AECB is intolerable in view of the importance of its regulatory function. The Committee believes that there are two steps to be taken to rectify this situation. First, the implementing legislation for the AECB should be altered to allow the Board to recover part of the costs of its licensing activities. [Although the Committee would prefer to see the AECB recover the greatest share possible of its costs through cost-recovery mechanisms, it does not believe that any useful purpose is served by arbitrarily stating that the Board must achieve full cost recovery.] If partial cost recovery alone does not provide sufficient additional funds, then the Parliamentary appropriation for the Board should be increased such that the AECB can fully discharge all of its responsibilities.

The Committee agrees with the view that both AECL and the nuclear industry have in the past not done a particularly effective job of educating the public about nuclear power. The advertisements and information kit recently produced by the Canadian Nuclear Association are a step in this direction, but the Committee believes that much more remains to be done if the public is to become well informed about Canada's nuclear power program. The Committee sees a role for the AECB to play in an objective public education program and recommends that such a function be established at the Atomic Energy Control Board.

C. The Radionuclide Business

The use of radioactive materials in medical applications dates back to the late 19th century. Wilhelm Roentgen discovered X–rays in 1895 and Henri Becquerel detected radioactivity in a sample of pitchblende in 1896. Pierre and Marie Curie achieved the chemical separation of radium from pitchblende, and for the first time a concentrated source of radioactivity became available.

Radiotherapy began in the closing years of the 1890s, when it was realized that radiation had biological effects. Superficial cancers were treated with radium before the turn of the century, but ignorance of the dangers of radiation led to the overexposure of both patients and practitioners during diagnostic and therapeutic work.

Scientists soon learned that there were at least three different types of radiation released by radioactive elements. These were called alpha, beta and gamma rays, corresponding to the first three letters in the Greek alphabet. Alpha radiation is the least penetrating, beta radiation is somewhat more penetrating, while gamma radiation is highly penetrating and requires the greatest amount of shielding for protection.

It was recognized that radiotherapy required the application of carefully controlled doses of radiation and, with the development of the X–ray tube in the 1920s, it became possible to design machines that possessed the required degree of flexibility

and control. World War II development of microwave technology and high-power radiofrequency generators led to the successful operation of microwave linear accelerators and their application to medical and industrial uses.

In Canada, a Commercial Products group was formed in 1946 within Eldorado Mining and Refining Ltd. to sell radium as a by-product of Eldorado's uranium business. Radium is very limited in supply, however, and it quickly became apparent that new products would be required for the burgeoning radiotherapy business. In 1947, the NRX research reactor was completed at Chalk River. This reactor, with its high neutron flux, allowed the production of a variety of radionuclides at activity levels higher than available elsewhere. In particular, the production of cobalt–60 provided the Commercial Products group with the new product required to replace radium. In 1949, Commercial Products began marketing radioisotopes produced by the NRX reactor. When Atomic Energy of Canada Limited was formed in 1952, Commercial Products was transferred from Eldorado to AECL.

In 1951, the group produced the first commercial unit to house cobalt–60 for cancer therapy. AECL has continued to develop its line of cobalt–60 machines, most recently adding the Theratron–C therapy unit. The company has introduced a fully integrated and computerized radiotherapy planning system (marketed as THERAPLAN) and a three-dimensional dosimetry unit for radiation beam analysis (marketed as THERASCAN). Today, there are more than 3,000 units in use for cancer treatment around the world. AECL Medical has designed and built the majority of these machines, as the world's largest manufacturer of cobalt–60 radiotherapy machines. As of May 1988, AECL Medical had installed 1,675 cobalt–60 units. These units had treated approximately 9.2 million patients and had added an estimated 13.8 million years of life to the 50% of the patients for whom treatment was deemed successful (adding an average of three years to the survival of these patients).

Canada is the world's largest supplier of cobalt–60, providing about 80% of this man-made radioisotope. Cobalt–60 is produced by irradiating natural cobalt–59 in a reactor and Ontario Hydro is AECL's principal supplier. The cobalt is sealed in zircaloy tubes which are vertically suspended in the CANDU reactors. The cobalt is irradiated for about one year during normal reactor operation and removed from the reactor during planned maintenance outages. Ontario Hydro then ships the cobalt to the Radiochemical Company.

Most cobalt–60 is used in the treatment of cancer but Ontario Hydro estimates that about 5% of the current market for this radionuclide is represented by food irradiation. Food irradiation is not done commercially in either Canada or the United States at this time but the technology is being applied in China, Japan and some European countries. Among its uses in this field are the elimination of salmonella in poultry and seafoods, the inhibition of fruit ripening and the elimination of the parasite *Trichinella spiralis* in pork. (Ontario Hydro, 1987a)

The need for self-contained irradiation units to conduct experimental work on

the effects of gamma radiation on various materials was recognized more than 30 years ago. A prototype gamma irradiation cell – the Gammacell 220 – was exhibited in New York in 1956 and was the precursor of both research irradiators and gamma irradiation processing on an industrial scale. As of early 1986, there were 132 industrial gamma irradiators operating in 39 countries. By far the largest supplier of these units was AECL Radiochemical Company, with 71 units installed in 29 countries. The closest competitors were the Soviet Union with 11 in domestic use, Marsh of England with nine units (four operating in the United Kingdom and five abroad), Commissariat à l'Énergie Atomique (CEA) of France with five units (three domestic and two abroad), and Radiation Sterilizers of the United States with five units in domestic service. (Canada, AECL, RCC, 1986)

Another area of application of irradiation is in radiation processing, which refers to the use of ionizing radiation from electron beam and gamma ray sources to initiate chemical changes in polymeric material or to destroy harmful microorganisms. The three main applications of radiation processing are:

1. sterilization of medical goods and preservation of food products;
2. treatment of polymers; and
3. curing of surface coatings.

There has been an enormous increase in the use of radiation to sterilize medical disposable goods since 1960. Gamma irradiation is preferred for thicker materials, where deep penetration is required, and electron beam equipment is preferred where the product is relatively thin. Food irradiation to inhibit sprouting, kill insects or enhance preservation is a controversial but promising application with a huge potential. Similarly, the treatment of wastewater and sludges by irradiation to kill pathogens is another potentially large area of application.

Polyethylene, polyvinylchloride, polyester and fluoropolymers are some of the plastics which can be used in irradiated products. Most natural and synthetic rubbers can be vulcanized by radiation. Radiation curable coatings – inks, adhesives, fillers and top coats – are finding progressively wider use in manufacturing.

The road to the present for AECL's Radiochemical Company was not uneventful. In the 1960s, a new technology – the linear accelerator or "linac" as it is sometimes termed – began to challenge cobalt–60 as the preferred means of treating cancers. By 1972, RCC had concluded that it needed to develop accelerators if it was to remain in the forefront of radiotherapy. Using profits from other parts of its operations, RCC worked on an advanced linear accelerator which it named the Therac 25 (T–25). The T–25 was supposed to become the new standard in linacs, being smaller, more powerful and less expensive than other accelerators on the market. Unfortunately, T–25 turned out to be a financial drain, drawing in profits from other operations as the design proved to be much more difficult than expected to perfect. The cost of the T–25 rose to a million dollars a unit, which meant that it could only reach a

limited market. As one observer described the situation, "The T–25 was a technological marvel and an economic nightmare."

In the early 1980s, the Radiochemical Company reached a crisis. The solution embarked upon was to create a new division, AECL Medical Products, which contained the money-losing accelerator work, cobalt therapy, medical simulators, treatment planning and manufacturing. RCC would remain the home of the profitable radioisotope business. AECL would withdraw from accelerator development. The Medical Products division came into existence in January 1985 and was in effect given one year to prosper. In a remarkable combined effort by the AECL board, management, union leaders, professionals and unorganized employees, AECL Medical did just that, although at the cost of trimming half of its former staff.

AECL Medical established the feasibility of a simple and inexpensive yet high-quality cobalt therapy unit for use in developing countries and in rural hospitals. Named the Phoenix to symbolize the hoped-for revival, a prototype was produced in just eight weeks. Another group of employees streamlined the existing cobalt therapy business, cutting costs and improving service. Excess capacity in AECL Medical's manufacturing capability began to be contracted out. As its advertising brochure states: "The Medical Division of Atomic Energy of Canada Limited is proud to offer a complete range of modern manufacturing facilities for your products or components through sub-contracting."

The result was a turnaround in the division's fortunes. After cutting its personnel from 486 at the beginning of 1985 to 244 fourteen months later, AECL Medical was working overtime by early 1986. A year later, the division had shown six consecutive months of profits and was rehiring some of its former employees.

Today, both the Radiochemical Company and AECL Medical are slated for privatization. RCC is to be sold to outside interests, with the proceeds of the sale accruing to the federal government. AECL Medical will be first offered for sale to its own managers and employees. Failing this, it will also be sold to outside interests.

While the Committee applauds the initiative that both of these divisions have shown in achieving their profitable positions, it is concerned that selling profitable elements of AECL will erode the financial position of the remaining components of the Corporation. How will the basic and applied research that AECL performs in the national interest be sustained if federal funding is reduced at the same time that profitable parts of the company are being sold off? The Committee is also concerned that enterprises developed in part at taxpayer expense and involving world-leading technology might be bought up by foreign interests.

The Committee recommends that the federal government enable AECL to hold an interest in private companies. If AECL were to retain a minority interest in a privatized Radiochemical Company and in an employee-owned Medical Products Division, it could continue to receive some financial benefits from the radionuclide

business that it had built up over 35 years. Customers would know that the parent company continues to have a direct interest in the success of the privatized RCC and AECL Medical. AECL's reputation in the international radionuclide business is held in high regard. At the same time, the RCC and AECL Medical could operate as private entities to joint venture, make acquisitions and move quickly on business opportunities which as part of a crown entity they cannot do. The Committee also recommends an explicit prohibition on foreign control of the RCC and AECL Medical, such as is embodied in frontier petroleum development. The Committee is not opposed to foreign interests holding a minority share in these privatized companies, but does not want to see the controlling interest leave Canada.

The radionuclide business is very much an international activity, one which AECL has carried on in more than 100 countries. From its base in Canada and five regional offices in the United States, the company is considering expanding its operations to a regional office in Europe, and thereafter into selected parts of the developing world. As such, AECL needs much more flexibility in its decision-making and financing than is currently the case. The Committee sees the virtue in privatizing these operations, but believes that these advantages can still be enjoyed while allowing AECL a residual role in the new entities.

Table 5 lists the principal radionuclides that have been applied by AECL to medical and industrial uses.

The medical applications of radioactivity have become very broad in recent years, and the use of industrial radioisotopes has also shown strong growth. In new albeit controversial areas of application, there are major opportunities open to AECL or its offspring. Food irradiation is an application of radioisotope technology which has generated recent debate, although it is clear that new approaches are needed to reduce food losses in storage, especially in the developing countries. Ionizing radiation passing through food leaves no residual radioactivity but does produce chemical changes. A 1986 report by the Advisory Committee on Irradiated and Novel Foods in the United Kingdom concluded that "there are no toxicologically significant qualitative differences between the radiolytic products in irradiated foods and the products in conventionally-processed foods, and that the chemical changes produced by irradiation of food are usually less than the changes found in foods processed by conventional methods whose safety is accepted" (Canada, Science Council, 1987, p. 9). Irradiation does alter the taste and texture of some foods and is not suitable for processing all food products. As is the case with other forms of food processing, irradiation does cause some nutritional loss.

Less well known is the application of radioactivity to the treatment of wastewater and sewage sludge, to counteract the pathogens which make them hazardous to humans. The Committee hopes that Canada will play an important role in these beneficial applications of radioactivity as it has in radiotherapy.

Table 5: Radionuclide Production and Use

Radionuclide	Half-Life	Type of Radiation	Principal Uses	Origin
Cobalt–60	5.3 years	Gamma	Sterilization Food irradiation Waste treatment Industrial radiography Gauging devices	Power and research reactors
Molybdenum–99	66 hours	Gamma	Raw material for the Technetium–99 (half-life 6 hours) generator; used in brain, bone, lung and kidney scans	Research reactors
Iridium–192	72 days	Gamma	Industrial radiography Pipeline weld inspection	Research reactors
Xenon–133	5 days	Gamma	Lung scanning	Research reactors
Iodine–131	8 days	Gamma	Thyroid imaging and therapy	Research reactors
Iodine–125	60 days	Gamma	Clinical laboratory test procedures Radioimmunoassay	Research reactors
Carbon–14	5,500 years	Beta	Synthesis of radioactive organic compounds for biochemical, biological and chemical research	Research reactors
Thallium–201	73 hours	Gamma	Cardiac imaging	Cyclotron
Gallium–67	78 hours	Gamma	Soft tissue tumor and abscess detection	Cyclotron
Iodine–123	13 hours	Gamma	Thyroid imaging Experimental nuclear medicine Brain and heart studies	Cyclotron

Source: Information sheet provided by AECL Radiochemical Company.

D. Spin-off Technologies

The Committee was not able to conduct a comprehensive review of new technologies which have been an outgrowth of Canada's nuclear power program. Members were able, however, to see selected examples of spin-off technologies and gain an appreciation of how the quality assurance standards developed by nuclear suppliers have benefitted Canadian manufacturing more generally. Several of these technologies and applications are briefly described in this section.

In its visits to Chalk River Nuclear Laboratories (CRNL), to AECL's Ottawa facilities, to CANDU Operations in Mississauga and to selected private sector companies in Ontario, the Committee was impressed with the less visible but nonetheless valuable offshoots of the domestic nuclear program. These activities, many of which are non-nuclear in character and application, are also at risk if the nuclear power program were to be phased out.

The SLOWPOKE Energy System is a heat generation and distribution system based on the SLOWPOKE thermal reactor. The original SLOWPOKE was developed in 1968-69 at Chalk River as a 20 thermal kilowatt pool-type reactor. The prototype began operation in 1970 and an additional eight units have subsequently been put into service. These SLOWPOKE research reactors are located at the University of Toronto, École polytechnique, Dalhousie University, the University of Alberta, the Saskatchewan Research Council, the University of the West Indies in Jamaica, the Royal Military College in Kingston, and the Radiochemical Company in Kanata. All of these reactors are licensed to operate unattended for periods up to 24 hours, although they are remotely monitored. Seven of the SLOWPOKEs operate on a highly enriched (93% U–235) fuel; the eighth and most recent uses a 20% U–235 fuel. All future SLOWPOKE research reactors will be fuelled with the less enriched uranium. (Lynch *et al*, 1986)

In temperate countries, more than 25% of primary energy consumption is in heating buildings. AECL has developed the SLOWPOKE Energy System for use in a district heating application, based on a 10 MWt heat source. The larger SLOWPOKE has the same main technical features as the smaller research reactor: it operates at atmospheric pressure without the need for a pressure vessel; heat transport occurs by natural convective cooling without the need for pumps; the reactor core is surrounded by a beryllium reflector to conserve neutrons; the reactor is remotely monitored and does not require an on-site operator; and the design is intended to be inherently safe. Inherent safety means that radiological protection is provided by the intrinsic characteristics of the reactor and does not depend upon engineered safety systems or operator intervention. The reactor has a negative reactivity coefficient, limiting power transients if reactor regulation is lost. A double containment system – made up of a steel liner and a surrounding concrete vault – prevents loss-of-coolant accidents. An air gap between the two containers is monitored for coolant leaks. The top of the reactor is enclosed by a steel cover plate to contain any radioactive gases escaping from the pool. The SLOWPOKE Energy System will run on a 4.9% U–235 enriched uranium, contained in 16 fuel bundles. Assuming a 50% annual load factor, the fuel

will need to be replaced every six years. (Lynch *et al*, 1986)

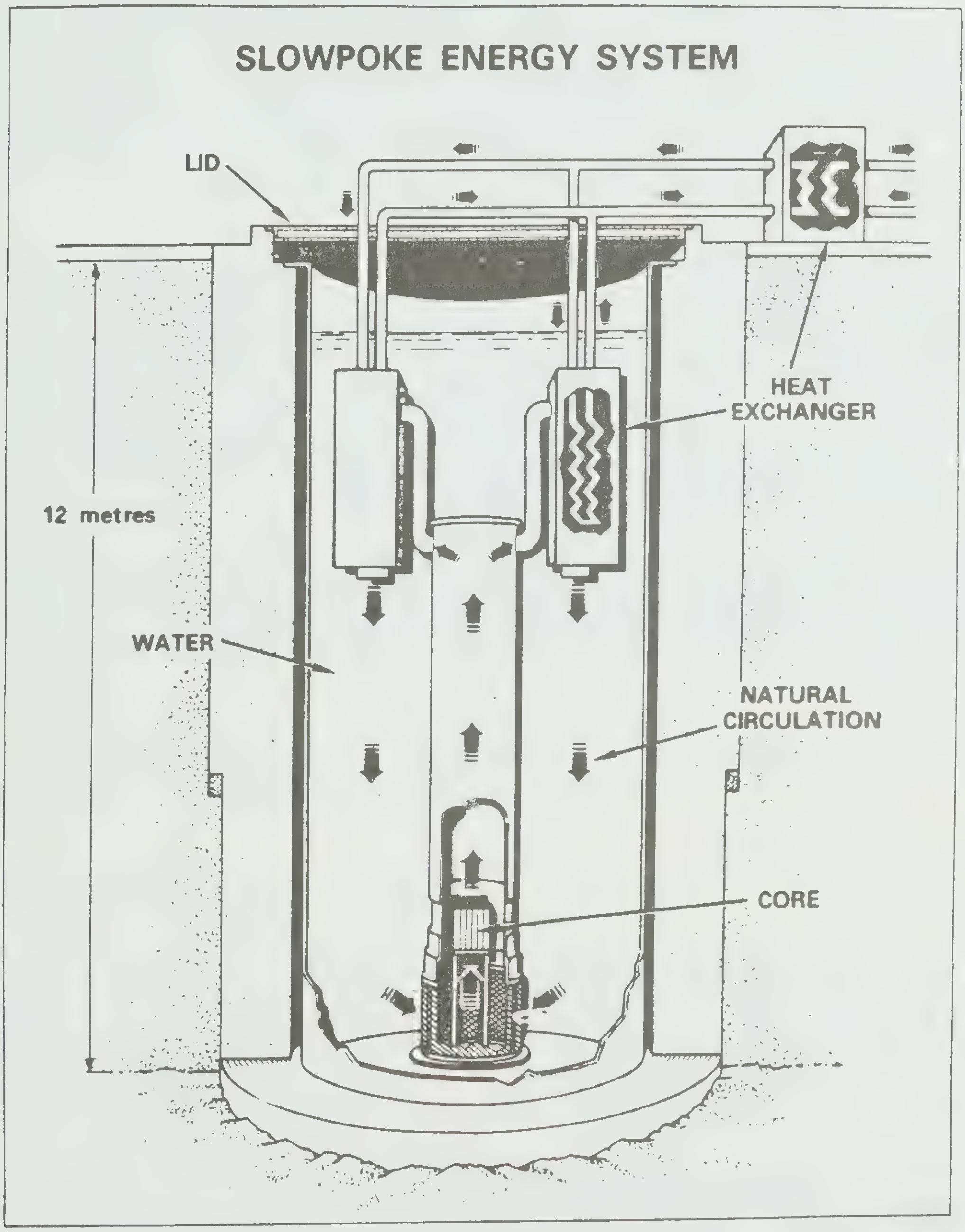
A 2 MWt demonstration unit has been constructed at Whiteshell Nuclear Research Establishment (WNRE) and will be operated to validate the design. The SLOWPOKE Energy System is claimed to be economically competitive with conventional heating in most regions of Canada. AECL calculates that heat can be supplied at a cost as low as 1.2 cents/kWh; a 10 MWt unit operating at a 40% load factor would supply heat at approximately 2 cents/kWh. This is said to be competitive with oil-fired systems with oil prices as low as $C 15 per barrel. The simplicity of the design with its elimination of pressurized systems and the short construction time (estimated at about one year) are the primary factors contributing to the low capital cost. (Lynch, 1987)

The SLOWPOKE Energy System is being developed in the Local Energy Systems Business Unit of AECL's Research Company at CRNL. Joint feasiblity studies between AECL and South Korea, China and Hungary have been started; Turkey, Romania and Yugoslavia have expressed interest in the concept.

The Research Company has developed high-performance and high-reliability pump seal technology which is now finding application in the U.S. space program. Failure of twin O-ring seals on the solid rocket boosters which lift the shuttle into space has been cited as the cause of the Challenger accident in 1986. The O-rings, made of synthetic rubber, are intended to prevent the escape of hot rocket gases through joints between the segments of the rocket boosters. Morton Thiokol Inc. of the United States, prime contractor to NASA for the solid rocket boosters, has contracted with AECL to draw upon the Company's expertise in fluid sealing technology. AECL's ability to field a multi-disciplinary team to work on the problem was an important factor in CRNL's winning the contract. (Canada, AECL, Research Company, 1987b)

A particularly interesting line of research at CRNL is investigating the link between cancer proneness and faulty DNA metabolism. Most human malignancies are believed to involve environmental factors in part, factors over which an individual may be able to exert some control. The concept of "equal exposure – equal risk" assumes a homogeneous response of individuals to cancer-causing agents. There is growing evidence, however, that there are subgroups within the human population with an abnormal sensitivity to specific carcinogenic agents. The varying ability of individuals to repair damage to DNA and restore normal DNA structure and function appears to be a determinant of the risk to those individuals from different cancer-causing agents. Scientists at Chalk River are attempting to devise tests which can be used to screen population groups and identify those who are at greater risk. For example, an individual abnormally sensitive to the effects of radiation should not be employed in an environment where he or she would be exposed to elevated levels of radioactivity. Similarly, an individual prone to develop cancer from overexposure to sunlight should avoid certain outdoor occupations. Such knowledge could be used to develop better strategies for the protection of human health, especially against occupational health hazards. (Gentner and Morrison, 1987)

Figure 8: The SLOWPOKE Energy System



Source: Lynch, G.F., *SLOWPOKE Energy System: Nuclear Technology in Local Energy Supply*, Local Energy Systems Business Unit, Whiteshell Nuclear Research Establishment, Atomic Energy of Canada Limited, Pinawa, Manitoba, February 1988, p. 5.

The SENSYS Business Unit of AECL, located in Nepean, Ontario, has developed an intelligent sensor system called Ferroscan. This real-time on-line sensor monitors the accumulation of iron wear debris in lubricating oil systems. Connected in groups and using appropriate software, Ferroscan sensors allow the user "to map equipment condition trends, plan for accurate maintenance schedules, and compare performance between operating units." By monitoring the rate and severity of wear in oil-wetted components, Ferroscan can detect the onset of equipment failure. Unlike other sensing systems, Ferroscan will measure accurately in oil-air systems containing up to 90% air. A particularly promising application is wear monitoring in military and commercial aircraft engines, although the technology potentially has a great range of use. SENSYS is also working on a variety of other sensor systems.

Chalk River Nuclear Laboratories and Inco Limited have teamed to produce an innovative piece of equipment known as the acoustic borehole meter. The meter, which resembles a bullhorn, is used to measure boreholes for depth, blockage and the presence of fissures along the length of the borehole. The battery-operated meter is said to work on any hole measuring 4 to 10 inches in diameter and 30 to 400 feet in length. It can determine if the borehole is blocked or open. Its principal application will be in accurately placing explosive charges to improve blasting efficiency in mining operations. (Canada, AECL, Research Company, undated)

CRNL has also developed a line of conventional and special-purpose eddy current probes to detect defects in metal tubes. Chalk River offers to custom design probes for those users with specific inspection problems. (Canada, AECL, Research Company, 1987a)

World Nuclear Power Development

The Committee selected four foreign countries for review of their nuclear power programs, to provide a broader perspective from which to examine the Canadian situation. The four chosen were Sweden, West Germany, France and the United States, which the Committee visited in that order. Officials in all cases cooperated fully to transmit as much information and understanding as possible in the limited time available in each country.

These four countries represent a broad range of nuclear experience in the industrialized world. Sweden has announced its intention to phase out all nuclear-electric power production by the year 2010, with the first of its 12 reactors to be decommissioned in 1995. At the other extreme, France derives a greater share of its electricity from fission power – approximately 70% in 1987 – than any other country and uses some of its reactors for tracking the variation in electrical demand (load following). West Germany has experienced difficulty in its nuclear program. The 300 MW fast breeder reactor at Kalkar is delayed by the refusal of the local government to issue an operating licence and the recent Hanau nuclear scandal has badly damaged the public image of West German nuclear power. West Germany is nonetheless nearing completion of the first phase of nuclear-electric generation in its national energy system. The United States is experiencing great difficulty in sustaining nuclear development and the future role of fission power is in question.

Before examining these four countries in detail, we begin with a brief review of world power reactor development. This provides a backdrop against which the nuclear programs of individual countries may be assessed.

A. An International Perspective

As of July 31, 1987, there were 418 operable power reactors in 26 countries. These reactors represented a total generating capacity of 308,166 megawatts (308.2 gigawatts). A further 130 reactors were under construction. (NEI, 1988, p. 10) In 1986, the combined output of all power reactors accounted for approximately 16% of the electricity generated globally.

The United States leads in the number of operable reactors, with 109 as of July 1987. The Soviet Union followed with 57 and France with 49. The United Kingdom was fourth with 38 operating reactors, Japan fifth with 37, West Germany sixth with 21, Canada seventh with 19 and Sweden eighth with 12. Table 6 lists the 26 countries with operable power reactors as of end-July 1987. The table also includes power reactors under construction, indicating that a further five countries will soon join the current group of nuclear-electric power producers.

Table 6: World Power Reactors in Operation or under Construction at July 31, 1987

Country	Operable Reactors Units	Operable Reactors MWe	Reactors under Construction Units	Reactors under Construction MWe
Argentina	2	1,005	1	745
Belgium	8	5,740	0	0
Brazil	1	657	2	2,618
Bulgaria	4	1,760	4	4,000
Canada	19	12,553	4	3,740
China	0	0	3	2,172
Cuba	0	0	2	880
Czechoslovakia	7	3,002	9	6,216
East Germany	5	1,835	6	2,640
Finland	4	2,400	0	0
France	49	46,693	14	18,477
Hungary	3	1,320	1	440
India	7	1,243	6	1,410
Italy	3	1,312	3	2,058
Japan	37	28,146	11	10,068
Mexico	0	0	2	1,350
Netherlands	2	540	0	0
Pakistan	1	137	0	0
Poland	0	0	2	930
Romania	0	0	5	3,395
South Africa	2	1,930	0	0
South Korea	7	5,816	2	1,900
Spain	8	5,810	2	2,022
Sweden	12	10,030	0	0
Switzerland	5	3,065	0	0
Taiwan	6	5,144	0	0
United Kingdom	38	12,796	5	3,822
United States	109	100,323	13	15,809
U.S.S.R.	57	34,334	29	29,620
West Germany	21	19,911	4	4,325
Yugoslavia	1	664	0	0
World Totals	**418**	**308,166**	**130**	**118,637**

Source: Nuclear Engineering International, "Reactor Statistics", *World Nuclear Industry Handbook 1988*, Reed Business Publishing, Sutton, England, 1988, p. 10.

Within the OECD, the proportion of nuclear-electric generation is higher than the 16% global average, amounting to almost 22% of all electricity produced during 1986. This average, however, conceals a wide range in nuclear-electric generating capacity: France produced 69.8% of its electricity at nuclear plants in 1986 while Turkey produced none. Belgium ranked second, generating 67.0% of its electricity from eight reactors; Sweden was third at 50.3%; and Switzerland was fourth at 39.2%. Canada, by comparison, produced 15.1% of its electricity in 1986 from nuclear stations and the United States 16.6%. Within Canada, nuclear power accounted for 46%, 43% and 3% of the electricity generated in 1986 in Ontario, New Brunswick and Quebec, respectively.

Japan is noteworthy for its long-term, highly-organized commitment to nuclear power. Given Japan's dependence on imported energy, this is not surprising from a strategic point of view: in 1985, Japan depended on imports for 80.5% of its total primary energy supply and 99.7% of its oil supply. At the time of the Arab oil embargo, 77.6% of the primary energy supply consisted of imported oil; only 0.6% was nuclear-electricity. In 1986, imported oil was down to 56.8% of primary energy supply and nuclear-electricity had increased to 9.5%. (Japan Industrial Location Center, 1988)

In July 1987, there were 37 operable Japanese power reactors representing 28,146 MW of installed capacity. Eleven units totalling 10,068 MW were under construction. In 1986, 24.7% of Japan's electricity came from nuclear units. (NEI, 1988) The nuclear development program calls for 53,000 MW of installed nuclear capacity in 2000 and 100,000 MW in 2030. The share which nuclear-electricity will claim of Japan's total electricity supply is projected to rise to 40% in 2000 and 60% in 2030. Fast breeder reactors will form the mainstream of Japanese nuclear development in the next century, allowing nuclear power to be established as a "quasi-domestic" energy source. (Japan, AEC, 1987)

Japan's rationale for exploiting atomic energy is evident in the following quotation from a report by the Japanese Atomic Energy Commission.

> Nuclear energy has huge potential, and its first practical use began in the field of power generation. Nuclear power generation has many outstanding advantages, such as the capability of generation of huge amounts of energy from a small amount of fuel, a low and stable generation cost, and a characteristic feature in the storage of the fuel, which allows the flexibility to cope with interruptions in the supply of fuel. Nowadays, nuclear power generation, together with oil and natural gas, is playing a principal role as an alternative energy to petroleum. The promotion of nuclear power generation in industrialized countries reduces the demand for petroleum, and contributes to easing the worldwide energy supply and demand situation.
>
> Such global scale environmental problems as acid rain, and the greenhouse effect accompanying the increasing concentration of carbon dioxide in the atmosphere, have caused serious concern in recent years, but on the other hand, nuclear power generation has less effect on the environment, and has the outstanding advantage of reducing the total release of pollutants into the atmosphere.

> Moreover, the promotion of nuclear power generation is also very important in releasing the limited and valuable fossil energy resources for use in other applications with higher added value. (Japan, AEC, 1987, p. 12)

Most Eastern European countries have also developed nuclear power programs. Bulgaria's four reactors in 1986 provided 30% of its electricity supply, Czechoslovakia's seven reactors produced 21%, Hungary's three reactors generated 18%, and East Germany's five reactors 12%. Soviet power reactors accounted for 11% of the electric power supply in the U.S.S.R. in 1986.

In the developing world, six countries were operating 24 commercial power reactors at the end of July, 1987. These were South Korea, Taiwan, Argentina, India, Pakistan and Brazil. Both Taiwan (with six reactors) and South Korea (seven reactors) derived approximately 44% of their 1986 electricity supply from fission power.

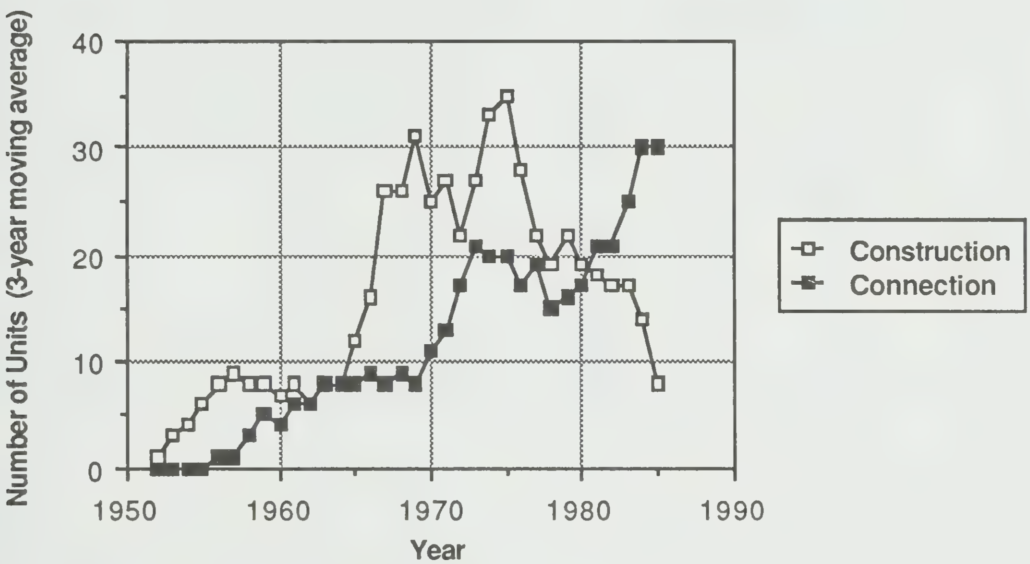
It is difficult to project world nuclear development beyond those reactor units already under construction. Forecasts of additions to generating capacity made in the 1960s and early 1970s were substantially reduced when it became apparent that the lower rate of growth in global energy demand following the 1973-74 and 1979-80 "oil crises" was not a passing phenomenon. What is apparent is that over at least the next 15 years the expansion in nuclear-electric power generation will slow markedly. Nuclear Engineering International provides the following projections of world nuclear-electric generating capacity in its most recent *Handbook* (1988, p. 11).

1985: 251.4 GWe (actual)	1990: 375.7 GWe
1995: 435.7 GWe	2000: 448.5 GWe

Slower growth in nuclear generating capacity over the remainder of the century reflects the downturn in the mid-1970s in reactor construction starts worldwide, given the time lag between start of construction and connection to the grid. Construction starts peaked in 1975, with work begun on 40 units that year. In 1986, construction was begun on only one unit. This is not an encouraging picture for those in the business of marketing power reactor systems. The reactor vendors with whom the Committee held discussions are rationalizing their operations and planning how they will survive the coming years of infrequent new orders. These vendors also expect that the early part of the next century will see a new surge in reactor construction, due to the declining availability of conventional light crude oil and growing environmental problems associated with the combustion of fossil fuels.

Figure 9 presents two sets of data: reactor construction starts and reactor connections to the grid. Both data sets are plotted as a three-year moving average because of the variability in the numbers on a year-to-year basis. Construction starts peaked in 1975; grid connections peaked in 1984-85, suggesting an average 10-year lag before units enter commercial service.

Figure 9: World Annual Reactor Construction Starts and Grid Connections, 1952-1985 (3-year moving average)



Note: Because of variability in the data, the graph has been plotted as a three-year moving average. The purpose of this illustration is to show the trends in reactor construction starts and grid connections, rather than the annual values.

Source: Modified from: Canada, AECL, *Nuclear Sector Focus*, Corporate Public Affairs, Ottawa, September 1987, p. D-17.

Another feature of global development is the swing in reactor construction away from the Western industrialized nations towards the Communist bloc and the Third World. Whereas the developing and Communist countries accounted for 15.9% of world nuclear generating capacity in 1985, they are projected to account for 27.9% in the year 2000 (Canada, AECL, 1987, p. D-10; NEI, 1988, p. 11). India, Brazil, Bulgaria, Czechoslovakia and the Soviet Union are forecast to have from two to five times as much nuclear capacity in their generating systems at the turn of the century as they had in 1987 (NEI, 1988, p. 11).

Through 1986, Westinghouse had been the most successful reactor vendor outside of the Communist bloc, with 85 orders for its PWR reactors, representing 15.2% of the world total of 558 reactor orders (net of any cancellations). Framatome was second with 65 orders (11.6%) and General Electric third with 62 orders (11.1%). AECL's 31 reactor orders (5.6%) exceeded Kraftwerk Union's 26 orders (4.7%), but the KWU units represented a larger total generating capacity. The U.S.S.R. had ordered

93 reactors domestically, for 16.7% of the global total, and had export orders for 29 units (5.2%). Table 7 provides more detail on the cumulative total of reactor orders by vendor, net of any cancellations. Vendors are ranked in Table 7 by the generating capacity represented by their orders, not by the number of units ordered.

Table 7: Cumulative Number of Reactor Orders by Vendor at Year-end 1986

Vendor	Number of Units	Generating Capacity (GWe)	Percentage of Total Generating Capacity
Westinghouse	85	77.4	17.8%
Framatome	65	71.1	16.4%
U.S.S.R. (domestic)	93	69.6	16.0%
General Electric	62	52.0	12.0%
Kraftwerk Union	26	27.8	6.4%
Atomic Energy of Canada Limited	**31**	**21.4**	**4.9%**
United Kingdom	43	15.5	3.6%
Mitsubishi Heavy Industries	18	15.0	3.5%
Combustion Engineering	15	14.8	3.4%
U.S.S.R. (export/Atomenergoexport)	29	14.6	3.4%
Babcock & Wilcox	11	10.5	2.4%
Toshiba	10	9.0	2.1%
Skoda	15	8.7	2.0%
ASEA-ATOM	11	8.7	2.0%
Hitachi	6	5.4	1.2%
Dept. of Atomic Energy, India	10	2.3	0.5%
Ansaldo	3	2.0	0.5%
Miscellaneous	25	8.6	2.0%
Totals	**558**	**434.4**	**100.0%**

Source: Nuclear Engineering International, "Reactor Statistics", *World Nuclear Industry Handbook 1988*, Reed Business Publishing, Sutton, England, 1988, p. 15.

The range in demand for electricity worldwide is revealed in statistics of per capita consumption. Table 8 presents per capita use of electricity in 23 selected countries in 1985. It is noteworthy that the top four nations are northern-latitude countries and that two of the four – Canada and Sweden – have well-developed nuclear power programs.

Table 8: The Per Capita Consumption of Electricity in Selected Nations in 1985

Country	kWh/Person	% of World Average Consumption
Norway	21,950	1,127%
Canada	**16,485**	**846%**
Iceland	15,833	813%
Sweden	15,661	804%
Qatar	11,415	586%
Luxembourg	10,811	555%
Finland	9,998	513%
United States	9,652	496%
New Zealand	8,708	447%
Australia	7,727	397%
East Germany	6,839	351%
West Germany	5,666	291%
U.S.S.R.	5,450	280%
France	5,072	260%
Japan	4,440	228%
South Africa	4,356	223%
United Kingdom	4,157	213%
World Average	**1,950**	**100%**
Brazil	1,316	68%
Mexico	1,177	60%
Egypt	474	24%
China	359	18%
India	165	8%
Nigeria	61	3%

Note: The world average has been calculated approximately using the values given for certain countries.

Source: Canada, AECL, *Nuclear Sector Focus*, Corporate Public Affairs, September 1987, p. C-12.

A startling feature of Table 8 is the broadness of the range in per capita electricity consumption. For example, on a per capita basis, Canadians use 270 times more electricity than Nigerians. This reveals the immense gap that exists between industrialized and developing countries in their consumption of electricity, and the enormous potential in the developing world for growth in demand for electricity, with all of its implications.

An average global value for per capita electricity consumption was not included

in the source for Table 8 and has here been calculated using the percentage of world average consumption given for the various countries.

B. The Swedish Nuclear Power Program

1. History of Swedish Nuclear Development

With an area of 450,000 square kilometres (174,000 square miles), Sweden is the fourth largest country in Europe but has a population of less than 8.4 million. Over 85% of the population lives in the southern half of the country; Stockholm has almost 1.5 million inhabitants.

During World War II, the Atlantic blockade of Allied shipping by German submarines illustrated the peril of depending on imported fuels. When oil imports rose sharply in Sweden after the war, warnings were raised. The Swedish commitment to nuclear power in the 1950s was motivated in part by the desire to restrain these imports. Unlike most countries, nuclear power in Sweden was first viewed primarily for application in district heating systems. One reactor for this purpose (Ågesta, a 60 MWt reactor with 20 MWe later added to its output) was constructed underground in Stockholm and subsequently dismantled in the mid-1970s. Interest then shifted to using nuclear reactors for combined electricity and heat production (cogeneration). In a critical decision in the 1960s, a nuclear cogenerating station planned for the city of Västerås was cancelled and replaced by an oil-fired system. Since electricity production and distribution are separate functions in Sweden (in 1946, the State Power Board was granted the exclusive right to build and operate the bulk power grid), this was a serious setback to the producers who favoured the expansion of nuclear power. Development then shifted to the generation of nuclear-electricity at large, central stations, while some municipalities built their own oil-fired cogenerating plants. (Sweden, Secretariat for Future Studies, 1977) Prior to the 1970s, "good" energy policy was seen principally as policy which provided the general community with the cheapest energy possible.

At the time of the Arab oil embargo, Sweden depended on imported oil for about 73% of its primary energy needs. In 1975, the Swedish Parliament (Riksdag) instituted an energy policy which was intended to shape energy development until 1985. A major thrust of this policy was to maintain a range of energy options for the future. One goal of the policy was to reduce the annual rate of increase in energy demand from 4.5% to 2%. This reduction was seen not as an end in itself but as a means to curtail oil imports, to restrain the growth in nuclear-electric power production and to hold back hydro-electric development. The continued use of nuclear power had by then become the subject of vigorous debate, and the Riksdag decided in the 1975 policy to restrict nuclear power development through the year 1985 to existing sites and to 13 reactors in total. The new energy policy stressed freedom of action, which in practical terms meant developing energy alternatives (in both supply and demand) so

that Swedes would not become "prisoners of the energy system" (Sweden, Secretariat for Future Studies, 1977, p. 15).

The March 1979 accident at unit 2 of the Three Mile Island nuclear generating station in Pennsylvania had a major impact on Swedish public opinion. An advisory referendum on the future of nuclear power in Sweden was conducted by the government in 1980, the fourth public referendum held in the country's history. This referendum contained three options, none of which provided for the retention of nuclear power. The text of the three options follows (as translated into English).

> ***Alternative 1:*** Nuclear power is to be phased out at the rate which is possible with due regard to the need for electric power to maintain employment and prosperity. In order among other things to reduce dependence on oil, and pending the availability of renewable energy sources, use will be made of not more than the twelve nuclear reactors which today are in operation, ready for commissioning or under construction. There is to be no further expansion of the nuclear power sector. Safety considerations will decide the order in which the reactors are to be taken out of service.
>
> ***Alternative 2:*** [Consisted of the text of Alternative 1 plus the following text printed on the reverse side of the ballot] Energy conservation is to be vigorously prosecuted and given further encouragement. The most disadvantaged groups in society are to be protected. Measures are to be taken to steer the consumption of electricity with the aim, among other things, of preventive direct-acting electrical heating in new permanent building development. Research and development activities concerning renewable energy sources are to be stepped up under public auspices. Measures to improve environmental standards are to be taken at nuclear power stations. A special safety study is to be carried out for each reactor. A safety committee including local representatives is to be appointed at every nuclear power station for purposes of public supervision. Electricity production in oil-based and coal-based condensation [thermal generation] is to be avoided. Principal responsibility for the production and distribution of electrical power is to be vested in society. Nuclear power stations and other future facilities of importance for the production of electricity are to be owned by national and local authorities. Excess profits accruing from hydro-electric power production are to be sequestered by means of taxation.
>
> ***Alternative 3:*** No further expansion of nuclear power. Closure within no more than ten years of the six reactors now in service. A conservation plan for the reduction of dependence on oil is to be based on: continued and intensified energy economization; greatly increased efforts to develop renewable energy sources. Stricter safety requirements are to be imposed on operational reactors. No unactivated reactors are to be commissioned. No uranium extraction is to be permitted in Sweden. If current or future safety analyses so require, this Alternative naturally implies an immediate shut-down. The campaign against nuclear weapons and their proliferation is to continue. No fuel reprocessing is to be allowed. Exports of reactors and reactor technology are to be discontinued. Employment to be boosted by means of alternative energy production, and more extensive upgrading of raw materials.

Of those Swedes entitled to vote, 75.6% cast a ballot, the highest level of participation in any of the four referenda. The results were:

Alternative 1: 18.9% Alternative 2: 39.1% Alternative 3: 38.7%

Only 3.3% of the ballots cast were blank.

Based on the results of the referendum, the Swedish Government announced that there would be no new nuclear power development, that the power reactors then under construction would be allowed to enter commercial service, and that all power reactors would be decommissioned by the year 2010. The Government decided that it was not possible at the time to specify when the phase-out of nuclear generation would begin but that the order of decommmissioning would be established on the basis of safety considerations. The construction of reactors for heating purposes alone was also prohibited, as was the construction of breeder reactors. The rate of phasing out nuclear generation was to be governed by the need for electric power to sustain employment and the national welfare.

In 1985, the previous 10-year energy policy having run its course, the Swedish Government issued a new statement of policy. This took the form of a Bill on Guidelines for Energy Policy, which was approved by the Riksdag without major alteration. This policy reaffirmed the Government's commitment to abandon nuclear power by 2010, to be achieved through energy conservation, the expanded use of district heating, the introduction of new energy sources and technologies, and continuing energy research and development. The policy also proposed to keep the level of Swedish energy use unchanged from about 1990 onwards. Efforts to reduce Sweden's dependence on oil were to continue. As the Government summarized its policy:

> During the rest of the 1980s the main aim of energy policy should be to *complete the reshaping of the energy system* from oil to renewable and indigenous energy sources, while gradually creating the conditions for a phasing out of nuclear power. An aspect of this reshaping process is the creation of an energy system that is less sensitive to international supply disruptions and which results in improved security of supply. (Sweden, Ministry of Industry, 1986, p. 7)

Sweden's *Act on Nuclear Activities* came into force in 1984. This Act clarified the responsibilities of the state and the electric power industry for nuclear safety. It required that all licencees of power reactors together prepare a comprehensive program of research and development in radioactive waste management, including final disposal, specifying all measures to be undertaken for at least six years in advance. The program is submitted to the Government every three years for evaluation, beginning in 1986. The Act also restated a requirement that had become law in 1976, that any power reactor being loaded with fuel for the first time must hold a special permit, granted only if the reactor operator:

> 1. has proved that there is a method for the handling and final disposal of spent nuclear fuel and radioactive waste deriving from it which is acceptable with regard to safety and radiation protection, and
>
> 2. has presented a programme for the research and development work necessary for ensuring that spent nuclear fuel from the reactor and radioactive waste deriving from it can be handled and finally disposed of in a safe manner. (Sweden, Ministry of Industry, 1984, p. 4)

The five reactors commissioned prior to 1976 were not affected by this stipulation, but the remaining seven have had to comply. The concept of deep geologic burial of high-level radioactive waste was advanced by the utilities and accepted by the Government as a safe disposal method.

The *Amended Act on the Financing of Future Measures for the Disposal of Spent Fuel* also came into force in 1984. This Act requires that reactor licencees shall defray the costs for:

1. the safe handling and final safe disposal of spent nuclear fuel from the reactor and radioactive waste deriving from it;

2. the safe decommissioning and dismantling of the reactor installation;

3. the performance of the research and development work necessary for the conditions referred to under subsections 1 and 2 to be met. (Sweden, Ministry of Industry, 1984, p. 11)

In addition to the above costs, reactor licencees are required by the legislation to defray costs incurred by the State in supplementing the R&D work of the licencees, certain administrative and other costs incurred in enforcing the Act, and costs incurred in the monitoring and inspection of final repositories. To accumulate the funds considered necessary to cover these costs, the licencee must pay an annual fee to the State for as long as the reactor is in operation. Those fees accumulate in accounts for each utility group. The rate is set by the State and is related to the amount of electricity delivered from the reactor. The fee is currently set at 0.019 Skr/kWh (approximately equivalent to 0.0037 $C/kWh or 3.7 mills/kWh). [The currency conversion rate used is 1 Swedish krona = 0.1923 Canadian dollar. The derived Canadian values are rounded.] These fees are bringing in 1,200 million Skr ($C 230 million) annually, of which about 600 million Skr ($C 115 million) is spent each year for the ongoing costs of the program. To the end of 1987, 3,900 million Skr ($C 750 million) had accumulated in the utility accounts. The total estimated future cost of the program is 38,000 million Skr ($C 7,310 million). The last year for collection of fees is 2010, but much of the spending comes later, with the largest expenditure being the final repository.

Some Swedes doubted that the Government would in fact end the use of nuclear power, given the difficulties in replacing this energy source. The Chernobyl accident of May 1986, with its radioactive fallout on Sweden, has stiffened government resolve and hardened public opinion. At the time of the Committee's visit to Sweden, legislation had been introduced in the Riksdag which would compel two reactors – one at Barsebäck and one at Ringhals – to be taken out of service in 1995 and 1996. The Committee understands that this legislation has now been passed. The Barsebäck reactor is privately owned by the Sydkraft power company and will not have reached the end of its useful life in 1995. Thus the Swedish Government will be faced with the question of financial compensation for the privately owned reactors that it will begin forcing out of service in 1995.

2. The Current Power Reactor Program

Sweden has 12 operating power reactors, with a net installed generating capacity of 9,663 MW. Nine are BWRs designed and installed by ASEA-ATOM (now part of ASEA/Brown Boveri), and three are Westinghouse PWRs. These 12 units are located at four stations. Three BWRs are situated at Oskarshamn on the Baltic coast about 300 km south of Stockholm. Three BWRs are located at Forsmark on the coast 150 km north of Stockholm. Two BWRs at Barsebäck lie across The Sound from the Danish capital of Copenhagen. The Ringhals station on the west coast about 60 km south of Göteborg has three PWRs and one BWR. Sweden's BWRs have the best average annual load factor – 82.5% in the 12-month period ending June 30, 1987 – of any country operating four or more reactors of this type (Howles, 1988, p. 22). No additional reactors are under construction or planned.

The 12 Swedish reactors are listed in Table 9. These units accounted for 15% of the country's total supply of primary energy in 1986.

Table 9: Sweden's Operating Power Reactors at 1 January 1988

Reactor Unit / Type	Commercial Operation	Net Electrical Output	Contractor
Oskarshamn 1 / BWR	1972	440 MW	ASEA–ATOM
Oskarshamn 2 / BWR	1975	595 MW	ASEA–ATOM
Oskarshamn 3 / BWR	1985	1,070 MW	ASEA–ATOM
Ringhals 1 / BWR	1976	750 MW	ASEA–ATOM
Ringhals 2 / PWR	1975	800 MW	Westinghouse
Ringhals 3 / PWR	1981	915 MW	Westinghouse
Ringhals 4 / PWR	1983	915 MW	Westinghouse
Barsebäck 1 / BWR	1975	595 MW	ASEA–ATOM
Barsebäck 2 / BWR	1977	580 MW	ASEA–ATOM
Forsmark 1 / BWR	1981	970 MW	ASEA–ATOM
Forsmark 2 / BWR	1981	970 MW	ASEA–ATOM
Forsmark 3 / BWR	1985	1,063 MW	ASEA–ATOM

Source: Sweden, Kärnkraftsäkerhet och Utbildning AB, *Summary of Operating Experience at Swedish Nuclear Power Plants 1987*, Stockholm, February 1988, p. 3.

In 1985, 42.4% of Sweden's domestic electricity production came from nuclear stations; in 1986 that share rose to 50.3%. This is the third largest share claimed by nuclear-electric generation in the OECD countries, with France leading in 1986 at

69.8% and Belgium second at 67.0%.

With all 12 reactors operational, the Swedish nuclear power program requires about 1,400 tonnes of uranium annually for fuelling. Approximately 90% of this amount is purchased under long-term contracts. For the period 1983-1992, about two-thirds of this uranium is being obtained from Canada, one-fifth from Australia, and the remainder from France and the United States. (Sweden, Ministry of Industry, 1986) In 1987, Canada exported 377 tonnes of uranium destined for Sweden after enrichment elsewhere, down from the 449 tonnes shipped in 1986 (Canada, AECB, 1988, p. 9). Although Sweden is known to possess deposits of uranium, potentially of commercial grade, no domestic mining of uranium has been undertaken, apparently on environmental grounds.

There are certain ironies in the Swedish nuclear situation. Sweden will shut down some of the world's most efficiently run BWRs, reactors which a Swedish commission has judged to be acceptably safe over their operating lifetime, while the Russians will continue to operate the RBMK reactor type that deposited the radioactive fallout on Sweden after the Chernobyl accident. To replace lost nuclear-electricity, the Swedes acknowledge that more fossil fuels will have to be consumed for some years to come, a curious exchange for a country that has been particularly affected by acidic precipitation. Sweden expects to import substantially larger quantities of natural gas as a substitute for nuclear-electricity. The Soviet Union may well supply much of this gas, the same country that Sweden has charged with frequent violations of its territorial waters by military submarines. Given the high priority that Sweden places on maintaining its neutral stance, such strategic dependence on the U.S.S.R. would be surprising.

3. Radioactive Waste Management

Sweden's radioactive waste management program is well organized and funded. The program is managed by a company created specifically in 1972 for this purpose: Svensk Kärnbränslehantering AB, or SKB (the Swedish Nuclear Fuel and Waste Management Company). SKB is owned by the four Swedish electric utilities which operate power reactors: Vattenfall (the Swedish State Power Board) (36%); Forsmarks Kraftgrupp AB (30%); OKG Aktiebolag (22%); and Sydsvenska Värmekraft AB (12%). The public service corporation Vattenfall is Sweden's largest electric utility, generating nearly half of the country's electricity and operating the four-unit Ringhals station. Forsmarks Kraftgrupp, which operates the three-unit Forsmark station, is jointly owned by Vattenfall and a private consortium. OKG Aktiebolag is an eight-company private consortium generating 40% of Sweden's electricity and operating the three-unit Oskarshamn station. The principal shareholder in OKG is Sydkraft AB, the largest private power company in Sweden and also the owner of Sydsvenska Värmekraft AB and the operator of the two-unit Barsebäck station. (Sweden, SKB, 1985) The Swedish nuclear power program is a mixed public and private enterprise.

SKB has the responsibility to develop, plan, construct and operate facilities for the management and disposal of spent nuclear fuel and other radioactive wastes produced at Swedish nuclear power stations. It is in charge of research and development activities within the field of radioactive waste management. SKB also handles matters of uranium prospecting, fuel enrichment, fuel reprocessing and uranium stockpiling for the Swedish nuclear power industry.

Three state agencies work closely with the SKB. The National Institute of Radiation Protection, SSI (Statens strålskyddinstitut), and the Swedish Nuclear Power Inspectorate, SKI (Statens kärnkraftinspektion), have regulatory functions. The National Board for Spent Nuclear Fuel, SKN (Statens kärnbränslenämnd), has a financial authority, collecting fees from reactor operators and holding program funds.

The Swedish National Institute of Radiation Protection, SSI, is contained within the Ministry of Environment and Energy, and administers the *Radiation Protection Act* and the Radiation Protection Ordinance. Since 1965, SSI has been the highest authority in Sweden on radiation protection. The Institute operates 25 measuring stations across the country, recording natural radiation levels. It also makes regular measurements of individual doses received by people working with ionizing radiation and today is monitoring about 14,000 people. In the field of nuclear power, SSI regulates the release of radioactivity at nuclear stations, reviews radiation protection requirements at these facilities, and prescribes dose limits for personnel. All transportation of radioactive material is supervised by SSI. The SSI and the National Rescue Administration are jointly responsible for emergency planning for nuclear power accidents. (Sweden, SSI, 1987)

The Swedish Nuclear Power Inspectorate, SKI, is the regulatory body established under the *Act on Nuclear Activities*. SKI's principal duties are to (Swedish Atomic Forum, undated, p. 33):

- evaluate the design of nuclear facilities from a safety point of view;
- formulate guidelines for safety and inspect nuclear facilities;
- survey and evaluate operational experience, and initiate safety precautions;
- inspect and account for nuclear materials according to international and Swedish regulations in order to prevent the non-peaceful use of such materials;
- inspect and prepare regulations for handling and storing nuclear waste;
- initiate and direct research and development in the field of nuclear safety; and
- inform the public about the work being done on nuclear safety.

Direct responsibility for the safety of nuclear facilities lies, however, with the owners, who must comply with any directives issued by SKI.

SKI is assisted in its work by three advisory committees: The Reactor Safety

Committee (which advises regarding reactor safety and licensing), The Safeguards Committee (which advises on the safeguarding of fissionable material and on protecting nuclear facilities and the transport of nuclear materials against theft and sabotage), and The Research Committee (which evaluates and proposes research projects). (Sweden, SKI, undated)

The SKI performs a function in Sweden similar to that of the Atomic Energy Control Board in Canada. The Committee notes that SKI has an Information Secretariat, whose "foremost function...is to inform the public of the work being done by SKI in the field of nuclear safety...Information on SKI's positions on various nuclear safety matters is aimed at the mass media, interest organizations and local safety committees as well as politicians, private persons and companies." (Sweden, SKI, undated, p. 7) This is a role that the Committee recommends be more fully developed by Canada's AECB.

According to a resolution of the Swedish Parliament, every power reactor must undergo at least three safety analyses during its planned lifetime, in addition to the safety analysis carried out before a reactor is commissioned. These recurring analyses incorporate the operating experience of the reactor, the results of test programs at the reactor, and the results of Swedish and international work on reactor safety.

The Swedish National Board for Spent Nuclear Fuel, SKN, was created in 1981 and is the central administrative authority under the *Amended Act on the Financing of Future Measures for the Disposal of Spent Fuel.* This legislation established three principles of nuclear waste management (Swedish Atomic Forum, undated, p. 34):

(1) The producer of the waste shall undertake the necessary actions for management and disposal of the waste.

(2) The state has the ultimate responsibility of ensuring that the waste is disposed of in a manner which is satisfactory to the Swedish public.

(3) The costs of waste management shall be paid by those who benefit from the nuclear-electric power. The capital needed for post-operational waste management activities shall therefore be raised during reactor operation and be held available for future needs.

With the *Act on Nuclear Activities* of 1984, SKN's financial authority was supplemented with authority over the R&D program which the nuclear power utilities implement for the management and disposal of spent nuclear fuel and nuclear plant decommissioning. SKN has thus been given the supervisory and economic authority to ensure that these three principles are followed. SKN recommends to the Government what fee needs to be charged per kilowatt-hour of nuclear-electricity produced to cover all future costs of nuclear waste managment and disposal and nuclear plant decommissioning. This fee is set annually and paid by the utilities into special

accounts administered by SKN. Prior to 1981, the utilities developed internal reserves for these activities; SKN took over the accumulated funds when the fee system and the government accounts were established. Interest on these funds accrues at the prevailing rate. As the utilities spend money on waste management or decommissioning, SKN releases funds from the accounts to reimburse the utilities for these expenditures. (Swedish Atomic Forum, undated)

This policy presents an interesting challenge to SKN: expenditures on radioactive waste management and plant decommissioning are expected to be made until about 2050 or 2060, yet SKN can only collect the fees until the last reactor is shut down in 2010. How does the agency forecast what total expenditures will be in a program continuing some 70 years or more into the future? At this time, SKN does not know what the schedule of reactor shutdown will be beyond the two units to be taken out of service in 1995 and 1996.

The Swedish Government, by accepting the concept of deep geological disposal as embodied in what is termed the KBS–3 model, created a problem for itself. Accepting the concept meant that the nuclear utilities had satisfied the legal requirement for starting the remaining new power reactors. KBS–3 is the model which SKB (the Swedish Nuclear Fuel and Waste Management Company owned by the utilities) has subsequently built its R&D program around. The KBS–3 report was completed in 1983 and although subsequent research has not caused the Government to re-evaluate its conclusions about the safety of the KBS–3 concept, SKN would like SKB to broaden some of the R&D work, in order not to miss opportunities for improved technical solutions. This puts SKB in the position of being asked by the government agency which oversees its R&D program to spend more time and money investigating alternatives to the KBS–3 disposal system which the Swedish Government has already declared to be acceptable.

The Legal Requirement for Safe Disposal of Radioactive Wastes in Sweden

Under Swedish law dating back to 1976, nuclear power utilities have had to demonstrate that spent nuclear fuel can be safely handled and disposed of before being allowed to load fuel into new reactors and start operating them. The utilities submitted their first such research report, KBS–1, in November 1977 together with an application to fuel Ringhals 3 and Forsmark 1. Ringhals 4 and Forsmark 2 were subsequently added to this application. KBS–1 assumed that spent fuel would be reprocessed, which was then the preferred option in Sweden. In 1978, the KBS–2 report was submitted, based on the direct disposal of nuclear fuel without reprocessing. This report was accepted by the Government as the basis for approving fuel loading at the four reactors. In May of 1983, the KBS–3 report was appended to the fuelling applications for Forsmark 3 and Oskarshamn 3. KBS–3 developed and broadened the work of KBS–2; in June 1984, the Government granted fuelling permission for these last two Swedish reactors. The Government thereby acknowledged that the requirements of the law had been satisfied and that the utilities had demonstrated the existence of a method for disposing of spent nuclear fuel in an acceptably safe manner. (Sweden, SKB, 1985)

The KBS–3 approach has the spent reactor fuel emplaced in a 500-metre-deep repository in stable, crystalline bedrock. Copper canisters will be used to contain the spent fuel. When filled, the repository will be backfilled and sealed, and will not require further surveillance. Safety of the repository "is based on the fact that degradation of the canisters and subsequent transport of their contents with the groundwater to the surface of the ground will take such a long time that the radioactive substances will decay and be diluted to such a degree that they reach the biosphere only in harmless concentrations" (Sweden, SKB, 1985, p. 12). Site selection for the repository is set by SKB for 1990-92 and the choice of the engineered barrier system (that is, design of the repository, form of the emplaced radioactive waste, design of the canister containing the waste, and the nature of the buffer and backfill around the canisters) is to be made between 1994 and 1996. The siting application is to be made by 2000, the safety report submitted by 2006, construction of the repository started by 2010, and operation of the repository begun in 2020. Some critics of the program claim that this schedule does not allow for any unforeseen delays. (Sweden SKN, 1987b)

SKB works under the following guidelines for its waste management program (Sweden, SKN, 1987b, p. 31-32):

- The radioactive waste products generated by the Swedish nuclear power program shall be disposed of in Sweden.

- The spent nuclear fuel shall be finally disposed of without reprocessing.

- Technical systems and facilities shall fulfill high standards of safety and radiation protection and satisfy the requirements of Swedish authorities.

- In all essential respects, the radioactive waste problem shall be solved by the generation of Swedes utilizing electricity production from the nuclear power stations. That is, there will be no burden on future generations.

- A decision on the design of the final repository for spent nuclear fuel shall not be taken until around the year 2000, so that it can be based on a broad body of knowledge.

- The waste management systems shall be designed so that requirements for controlling fissionable materials can be fulfilled.

- The necessary technical solutions shall be arrived at within Sweden, although available foreign knowledge shall be gathered.

- The conduct of the work shall be subject to the continuing review of the regulatory authorities and the directives issued by them.

- The waste management activities shall be conducted openly and with broad public knowledge.

To advance its knowledge of the conditions for deep geological burial, SKB is operating an underground research facility for high-level waste disposal at the Stripa mine about 230 km west of Stockholm. At this facility, techniques are being developed to allow the design of a final repository in stable crystalline rock. Stripa is a former mine in an iron ore deposit. Work on the waste disposal program began here in 1976, when the ore body was mined out. Tunnels were excavated at the 360-metre-level in the mine in a granite bordering the ore body. Non-radioactive heating experiments were carried out at Stripa in a joint Swedish-U.S. project. Today the research centres on the detection and mapping of rock fracture zones, the measurement of groundwater flow and nuclide migration, and the use of bentonite clay for backfilling and sealing. (Sweden, SKB, undated(c))

Sweden's program of high-level radioactive waste disposal in stable, deep geological formations is similar to the programs of Canada and Switzerland, which the Swedes describe as "mature". Canada's R&D work in support of its disposal program was observed by the Swedes to be more advanced than their own in certain areas.

The disposal program for spent fuel is complemented in Sweden by a well-developed system for interim storage of all radioactive wastes and a disposal system for low-level and intermediate-level wastes.

All Swedish nuclear-electric generating stations are located along the coast and each has its own harbour facilities. SKB has established a complete transportation system for radioactive materials based on sea transport. Spent fuel is stored in water-filled bays at each reactor site for at least one year, following which it is loaded into casks and trucked onto a specially-designed, roll-on roll-off vessel, the *M/S Sigyn*, for shipment to a central storage facility for spent fuel. The spent nuclear fuel is placed in an 80-tonne shielded steel cask with a capacity of three tonnes of fuel. The transport cask sits on a frame and is hydraulically lifted by a vehicle which transports the frame and cask together. This cargo can be driven or lifted by crane onto the *Sigyn*, which can accommodate ten of these casks. The ship is also used to transport low- and intermediate-level wastes (reactor wastes) to a final repository at the Forsmark nuclear power station. *M/S Sigyn* makes approximately 30 trips per year between the four nuclear power stations, the central fuel storage facility and the repository for reactor wastes. (Sweden, SKB, undated(b))

M/S Sigyn is double-hulled, double-bottomed and fitted with several watertight bulkheads. This Swedish designed and French built ship is equipped with two independent propulsion systems; electric power is supplied from three generators, each of which can handle total ship demand. A sophisticated fire control system protects all parts of the vessel. A water-filled tank shields the crew quarters against radiation from the hold and concrete walls separate the engine rooms from the hold. Radiation monitoring equipment includes gamma and neutron detectors. (Sweden, SKB, undated(b))

The central storage facility for spent nuclear fuel at Oskarshamn is known as

CLAB. This pool storage system is designed to receive fuel from the four power stations for intermediate storage of about 40 years before final disposal. The fuel storage building has been excavated in bedrock and the roof of the 120-metre-long cavern is 25 to 30 metres below ground level. In its initial configuration, CLAB consists of four interconnected storage pools, each of which can hold 750 tonnes of spent fuel. The facility can be extended in the future with additional caverns constructed parallel to the first one. CLAB was commissioned in 1985 and built at a total cost of about Skr 1,700 million ($C 325 million). (Sweden, SKB, 1986)

A terminal vehicle transports the cask from the ship to CLAB and the the cask is unloaded in an air lock in the receiving building. The cask is lifted from the vehicle by crane, cooled to room temperature in a preparation cell, and then unloaded underwater by remotely-controlled handling machines. The spent fuel assemblies are transferred to storage containers and placed in predetermined locations in the storage pools. (Sweden, SKB, 1986)

Low- and intermediate-level radioactive wastes are sent to the SFR facility at Forsmark, a final repository for reactor wastes. Low-level wastes are defined as those wastes with such a low level of radiation that they can be handled without the need of shielding. The intermediate-level wastes must be shielded but do not require cooling. These wastes contain virtually no long-lived radionuclides and are considered harmless to human beings and to the environment after about 500 years. Under the most pessimistic assumptions used in the environmental impact assessment for SFR, these wastes would add a few per cent to natural background radiation in the area. SFR is located in bedrock 50 metres below the Baltic seabed. Water depth above the repository is five metres. This region of Sweden is still rebounding from the weight of the last ice sheet that covered the land until about 9,000 years ago. In 500 years, this area will be above sea level but the wastes will be essentially harmless by then. SFR is located beneath the Baltic because the groundwater regime is stagnant and no one will drill there in the future for fresh water. (Sweden, SKB, undated(a))

SFR consists of storage chambers and a silo in a series of rock caverns, reached by kilometre-long twin tunnels extending from land. The silo, the first of as many as four, will hold the most radioactive materials, primarily ion exchange resins solidified in concrete moulds or metal drums. The inside of the silo is divided into 2.5-metre-square cells running from top to bottom. Waste packages are placed in the cells and backfilled with concrete. The silo rests on a bed of sand and clay, and the space between the wall of the silo and the surrounding rock is filled with clay. Various types of packaging are being used for the wastes placed in the storage chambers, depending upon the radioactivity of the waste and the handling procedures at the nuclear power stations. SFR was completed in 1988 and the Committee visited this facility a few weeks before it began receiving reactor wastes. The first phase of SFR cost about Skr 740 million ($C 140 million). (Sweden, SKB, undated(a))

Studsvik Energiteknik AB is an energy research centre located about 100 km south of Stockholm on the Baltic coast. The Committee visited Studsvik because of its

similarities with Chalk River Nuclear Laboratories and because of its work in managing reactor wastes in particular.

Studsvik began life in 1947 as AB Atomenergi, a joint state-private enterprise. The early development of a heavy water reactor system was carried out here, until Sweden opted for the LWR design in the 1960s. Studsvik designed and built the Ågesta reactor for the Stockholm district heating system. In 1969, Studsvik became wholly state-owned and ASEA-ATOM was formed as a separate company, half owned by ASEA and half by the Government. In 1978, the state-owned AB Atomenergi was transformed into the private commercial enterprise Studsvik Energiteknik AB. Today Studsvik competes for its work and because its income expectations were not realized in 1985 and 1986, the company has had to reduce staff and reorganize its operations. In 1987, Studsvik's $C 100+ million income broke down as follows: about $30 million from the Swedish nuclear industry; $33 million from its export business; $12 million from Swedish nuclear agencies in bidded contracts; $10 million in fees for university research performed at its facilities; $12 million in special government asignments; and $3 million in government subsidies for R&D performed jointly with industry.

Studsvik treats low- and intermediate-level wastes from power reactors, hospitals, research facilities and industry. It also incinerates reactor wastes received from West Germany, with the ash being encapsulated in concrete or bitumen and returned to Germany for disposal. Studsvik has recently completed Project AMOS, a comprehensive program to modernize all of its waste facilities. This modernization included a new building for processing solid and liquid wastes, an underground interim storage facility, and harbour facilities to accommodate the *M/S Sigyn*. The Studsvik Incineration System is a modern, multi-chamber electronically-controlled incinerator designed to burn low-level wastes. The resulting ash is encapsulated in concrete. Waste volume is reduced by a factor of approximately 100 through incineration. This unit began operation in 1977 and through 1988 had burned about 3,500 tonnes of waste, ranking it as one of the leading radioactive waste incinerators in the world. Studsvik is supplying an incinerator of double this capacity for Oak Ridge Nuclear Laboratories in the United States. Other sales are in prospect. (Sweden, Studsvik Energiteknik, 1987)

Studsvik has also developed an induction furnace to melt irradiated metals. This avoids the difficulty in trying to decontaminate complicated structures like steam generator piping. The metal is cut up and melted; the resulting ingot is scanned to ensure that it is safe for recycling. If the radiation level is too high, the ingot is simply stored until the radioactivity declines to an acceptable level.

The Committee is impressed with the thoroughness and design of the Swedish radioactive waste management program. The Committee favours the idea of maintaining separate government accounts funded by the users of nuclear-electricity and dedicated to radioactive waste management and reactor decommissioning.

C. The West German Nuclear Power Program

1. History of West German Nuclear Development

The Federal Republic of Germany, the FRG or West Germany, has an area of 249,000 square kilometres (96,000 square miles) and a population of 61 million. The country is made up of 11 federal states, including West Berlin. The most populous is North Rhine-Westphalia with 17 million inhabitants. The capital city of Bonn and the city of Essen, home of the largest German electrical utility Rheinisch-Westfälisches Elektrizitätswerk (RWE), are located in this state. Both cities were visited by the Committee.

Responsibility for nuclear energy at the federal level rests with four departments. Support for nuclear energy R&D is the responsibility of the Federal Minister for Research and Technology. The application of nuclear energy as one of Germany's important energy sources rests with the Federal Minister for Economic Affairs. Nuclear safety regulation is the responsibility of the Federal Minister for Environment, Nature Conservation and Nuclear Safety. West Germany's international commitments in the nuclear area are handled by the Foreign Office. (Breest, 1988)

Electric utilities, which hold the reactor licences and operate the power reactors, are organized as private companies, although municipalities and the states can own shares in them. State licensing and superintending authorities execute federal nuclear laws on behalf of the central government, supervised by the Federal Ministry for Environment, Nature Conservation and Nuclear Safety. There has in the past been close cooperation between the federal and state governments in nuclear development, especially in financing West Germany's nuclear research centres and university research. The Social Democratic Party, however, declared nuclear power to be unsafe after the Chernobyl accident and wants all German nuclear-electric generation to be phased out within 10 years. The Social Democrats control some state governments and, since the federal government has delegated the authority to license reactors to the state governments, this cooperation has evaporated in some cases. The stalled Kalkar breeder reactor is caught in this political situation.

Research and development of nuclear power in West Germany was only allowed beginning in 1955, with the Paris Souvereignty Treaty. The German Government thereafter established major nuclear research centres at Karlsruhe and Jülich; entered into bilateral cooperation agreements with such countries as France and the United States; and joined the IAEA, the Nuclear Energy Agency of the OECD, CERN (the European Organization for Nuclear Research) and EURATOM (the European Atomic Energy Community). German industrial concerns collaborated with U.S. companies to foster reactor development – Siemens with Westinghouse for the PWR design, and AEG with General Electric for the BWR design. By about 1970, West Germany had become technically independent in reactor design; Kraftwerk Union (KWU) was established by Siemens and AEG-Telefunken to develop a German

nuclear power plant design and associated safety system. (Breest, 1988)

Not only had West Germany overtaken the lead of other industrial countries in power reactor development, it had begun to compete in the export market. In 1968, West Germany secured its first foreign order, the 320 MW Atucha reactor in Argentina. This was followed by the sale of a 450 MW reactor to the Netherlands in 1969, a 700 MW unit to Austria in 1971, and a 920 MW unit to Switzerland in 1972. (FRG, Federal Ministry for Research and Technology, 1974)

West Germany has based its commercial reactor program on the LWR, in both PWR and BWR designs. Looking to the future, it has also constructed a 15 MWe experimental high-temperature reactor (HTR) and recently completed a commercially-sized 300 MWe thorium high-temperature reactor (THTR). Because the HTR operates at a higher coolant temperature than the LWR, it can achieve a higher operating efficiency. Basing the HTR on the thorium cycle opens up another fuelling option. HTR reactors are also claimed to be inherently safer than LWRs.

An experimental 17 MWe sodium-cooled fast breeder reactor (FBR), which began operation at Karlsruhe in 1978, was the forerunner of the 300 MW Kalkar FBR. The Kalkar reactor is completed but the state government has refused to license its operation.

2. The Current Power Reactor Program

West Germany has 22 power reactors operating today, totalling 18,926 MWe of net installed generating capacity. A further three reactors are under construction and one completed reactor awaits licensing, the four units aggregating an additional 4,052 MWe. Six older units have been decommissioned. Nine reactor projects have been applied for but reduced energy demand in Germany makes their need questionable before the turn of the century. Information on the West German nuclear power program is contained in Table 10.

In 1986, 29.6% of West Germany's supply of electricity came from nuclear stations; in 2000, that share is projected to rise to 35%. However, opposition to continued nuclear power development has become stronger, especially with the political rise of the Green Party, and the German nuclear program is in difficulty. The most serious delay in the German program is the Kalkar 300 MW fast breeder reactor, a project which the West German Government initiated in 1972 in a cooperative program with the Netherlands and Belgium. Although the reactor has been ready for fuel loading since mid-1986, the state government of North Rhine-Westphalia refuses to issue an operating licence. RWE has a 68.85% interest in the West German holding company SBK (Schnell-Brüter-Kernkraftwerkgesellschaft mbH Gemeinsames Europäisches Unternehmen, Essen) which built and will operate Kalkar. The Dutch and Belgian electrical industries hold most of the remaining interest and a small share is held by British utilities. (RWE, 1988)

Table 10: West Germany's Operating Power Reactors at 1 January 1988

Reactor Unit / Type	In Operation	Net Electrical Output	Contractor
AVR Jülich / HTR	1969	13 MW	BB-Krupp
Obrigheim / PWR	1969	340 MW	Siemens
Stade / PWR	1972	630 MW	Siemens
Biblis A / PWR	1975	1,146 MW	Siemens-KWU
Biblis B / PWR	1977	1,240 MW	Siemens-KWU
Würgassen / BWR	1975	640 MW	AEG
Neckarwestheim-1 / PWR	1976	795 MW	Siemens-KWU
Brunsbüttel / BWR	1977	770 MW	AEG-KWU
Karlsruhe KNK-2 / Fast Breeder	1978	17 MW	Interatom
Isar-1 (Ohu) / BWR	1979	870 MW	AEG-KWU
Unterweser / PWR	1979	1,230 MW	Siemens-KWU
Philippsburg-1 / BWR	1980	864 MW	AEG-KWU
Philippsburg-2 / PWR	1985	1,268 MW	KWU
Grafenrheinfeld / PWR	1982	1,225 MW	KWU
Krümmel / BWR	1984	1,260 MW	AEG-KWU
Gundremmingen II-B / BWR	1984	1,249 MW	KWU
Gundremmingen II-C / BWR	1985	1,249 MW	KWU
Grohnde / PWR	1985	1,290 MW	KWU
Brokdorf / PWR	1986	1,307 MW	KWU
Mülheim Kärlich / PWR	1987	1,227 MW	RWE
Hamm-Uentrop / THTR	1987	296 MW	Konsortium THTR

Source: France, Commissariat à l'Énergie Atomique, *Les Centrales Nucléaires dans le Monde*, 1987 Edition, Paris, 1987, p. 16-17; Breest, H.-Ch., *Nuclear Energy in the Federal Republic of Germany*, Edition No. 101, Federal Ministry for Environment, Nature Conservation and Nuclear Safety, Federal Republic of Germany, March 1988, Figure 2.

Apart from the stalled Kalkar FBR, completion of the remaining three PWRs will end the current phase of West Germany's nuclear power program. Until growth in the demand for electricity picks up and until first generation power reactors are decommissioned and require replacement, the Committee was told that further reactor orders will not be placed.

SBK has a 16% interest in the French 1,200 MW Super-Phénix fast breeder reactor in Creys-Malville near Lyons. Shareholders in Super-Phénix are entitled to a share of the electricity generated proportional to their interest. The RWE holding is three-quarters of the SBK share, or 12% of the project. RWE also has a 7.5% interest in a proposal to construct a new nuclear power station in Switzerland and SBK holds a 51% share in a European consortium proposing to build a prototype breeder reactor in West Germany. (RWE, 1988) These examples demonstrate the international cooperation among Western European utilities in reactor construction, especially in breeder reactor technology, which also spreads the burden of the financial risk. The problems in licensing Kalkar, however, threaten to upset this cooperation.

The view expressed to the Committee by the West German Government was that nuclear energy is an essential component of the national energy system – nuclear and solar are the energy forms of the future. The principal challenge is to tailor these energy forms to the West German situation. Maintaining environmental quality is one of the main rationales for the West German nuclear program; the accumulation of carbon dioxide in the atmosphere is considered to be one of the most critical environmental issues of the future. According to Government representatives, the most important public issue in the German nuclear program today is resolving the radioactive waste management problem.

In the aftermath of Chernobyl, the German Reactor Safety Commission reexamined West Germany's reactors and concluded that no doubt had been cast on their safety. The German reactor program has never suffered a significant accident. As an RWE executive expressed it, "Chernobyl proved that it is possible to construct a reactor so badly and operate it so badly that an accident can occur. We already knew that."

RWE believes that no new nuclear generating capacity will be required in West Germany in the remainder of this century. Nonetheless, the utility will continue to work with KWU to plan for the reactor system of the year 2000. This is considered essential to preserve and expand the base of knowledge in German reactor development. Several billion dollars may have to be invested to preserve the nuclear option until it is once again required in West Germany. This is regarded as a necessary investment in the country's future.

Under current conditions, nuclear power is the most cost-effective generating option for West Germany. RWE quoted 10-12 pfennig/kWh as the projected average cost of nuclear-electricity in the early 1990s, compared with a 15-17 pfennig/kWh projected cost for coal-fired electricity using domestically mined coal and given the

strict new environmental controls which coal-fired plants will have to meet. This cost differential is expected to widen with time. RWE told the Committee that it is spending six billion marks (about $C 4 billion at the current exchange rate) to control acid gas emissions at its 11,000 MW of lignite-fired generating capacity. If Germany's coal-fired plants were instead to burn imported coal, at today's depressed prices, they could just barely match nuclear power at its current cost.

Public liability in West Germany for nuclear accidents is split between the utilities and the state. The primary responsibility – up to one billion marks (approximately $C 675 million at the time of writing) – lies with the producer of the electricity. The Federal Government assumes an unlimited liability should claims exceed that amount.

The Germans have also been concerned with protecting their reactors against either sabotage or accident. Germany has tried to engineer its reactors so that an operator or a saboteur couldn't harm the outside environment even if successful in wrecking the reactor. Early German reactors were built with a concrete containment shell about 0.5 metres thick, designed to survive the impact of a light aircraft striking the shell. Newer reactors are protected by a 1.8 metre thick shell, designed to survive the impact of a fully loaded Tornado fighter aircraft weighing 17 to 18 tonnes. A jumbo jet represents less of a hazard because its mass would be distributed over a much larger section of the containment shell in an impact. As one official observed, the probability of an aircraft crashing into a stadium containing 50,000 people is higher and stadiums are not protected from such events, whereas Germany's reactors are.

Despite an admirable reactor safety record, one of the most advanced radioactive waste management programs in the world, a lack of indigenous energy resources apart from coal and serious air pollution problems, West Germany is still facing substantial public opposition to its nuclear power program.

3. Radioactive Waste Management

The West German nuclear program also includes uranium enrichment facilities, fuel fabrication plants for uranium oxide and mixed oxide fuel production, spent fuel and reactor waste interim storage, spent fuel reprocessing (to be done at a facility being developed at Wackersdorf in Bavaria) and the final disposal of radioactive wastes (with a final repository planned for the Gorleben salt dome). Until the Wackersdorf reprocessing plant is operational, spent fuel from the German reactors is being reprocessed under contract by the French company COGEMA and the British company BNFL (British Nuclear Fuels Limited).

West Germany has also seen its radioactive waste management program become the subject of strong public opposition, despite the Government's belief that it has put a strong, well-conceived program in place. Research has focussed on the use of salt as a disposal medium. In 1965, the disused Asse salt mine was purchased by

the federal government to develop methods for storing radioactive wastes. From 1967 to 1978, approximately 124,500 drums of low-level wastes and 1,300 drums of intermediate-level waste were stored in the mine. An amendment to the *Atomic Energy Act* in 1976 resulted in the expiry of storage licences in 1978. Since then Asse has been used to continue R&D into salt as a disposal medium for radioactive wastes. Asse is judged unsuitable for high-level waste disposal but may be reopened as a repository for low- and intermediate-level wastes. (FRG, PTB, 1985)

In the 1970s, interest in using geologic formations other than salt led to investigation of the disused Konrad iron mine near Asse as a repository for wastes with low thermal impact. The Konrad mine is exceptionally dry, being overlain by clay-rich strata. The position of the mine workings at a depth of 800 to 1,300 metres is also a favourable feature. Licensing procedures have begun to establish the Konrad mine as a repository.

Also in the mid-1970s, the Gorleben salt dome north of Asse was selected as a provisional site for a repository to contain all categories of radioactive waste. If the site investigation confirms its suitability and the licensing procedure confirms the site, construction of a repository could start after 1995 with the emplacement of wastes at the turn of the century.

Work in the Asse salt mine and the subsequent studies in the Gorleben salt dome, both near the northeastern border with East Germany, triggered public opposition which has delayed the program. The intermediate storage facility for spent fuel elements at Gorleben is technically operational but has not entered service because of litigation. Construction of a second such facility in Ahaus is suspended by a court order. A storage facility for low-level radioactive waste at the Gorleben site is functional. Licensing is under way to construct a pilot plant at Gorleben for the conditioning of high-level wastes prior to final disposal in a facility also proposed for this salt dome. A 1987 accident in an exploratory shaft has set back the work schedule on the disposal facility by about a year. The disposal program is studying the emplacement of both reprocessing wastes and spent fuel at Gorleben. Approximately one billion marks (almost $C 700 million) has already been spent in this effort.

Under West German law, electric utilities must demonstrate in a six-year moving plan that they can manage spent reactor fuel. The Wackersdorf reprocessing plant and the program for disposing of reprocessing wastes at Gorleben are part of this demonstration. If the utilities instead decided to go to the direct disposal of spent fuel, they would no longer meet the requirements for their operation. Until direct disposal is sufficiently well studied to qualify as a safe disposal method, the utilities cannot abandon the Wackersdorf program for reprocessing irradiated fuel. The West German representatives observed that theirs was the only country to tentatively site a disposal facility, but this is no longer the case since the United States legislated the Yucca Mountain site in Nevada for its disposal facility (subject to site verification work).

Electricity consumers will pay for the waste management program entirely,

since German electric utilities absorb the costs and in turn incorporate them into the rate base. The state governments are responsible for administering the program but not for funding it.

D. The French Nuclear Power Program

1. History of French Nuclear Development

France has a population of 56 million inhabiting a country of 549,000 square kilometres (212,000 square miles). The Committee's visit to France was limited to Paris and its immediate surroundings. Given the centralized nature of the French Government, however, this still afforded Committee members the opportunity to speak with officials from many of the relevant agencies in the nuclear field.

The French reactor program was initially based on a graphite-moderated and gas-cooled reactor fuelled with natural uranium. Nine reactors of this type were built, beginning with the 2 MW Marcoule G–1 reactor which was connected to the grid in 1956 and ending with the 540 MW Bugey–1 reactor connected in 1972. Four of these reactors are still in service. France began building PWR reactors in the 1960s, with the 310 MW Chooz A–1 unit being the first of this type to see service in 1967. In 1969, France decided to base its nuclear power program on the PWR, while recognizing that the breeder reactor was likely to play a key role in long-term nuclear development.

The problems caused by the 1973 oil embargo convinced France that energy independence was vital to the country's interests. In 1974, the French Government charged Electricité de France (EdF), the national electric utility, with the task of developing a nuclear power program capable of providing one-third of the nation's total energy needs by the year 1990. In 1987, France generated a greater share of its electricity – 70% – from nuclear units than any other country. France is second only to the United States in installed nuclear generating capacity. Almost one-sixth of nuclear reactor construction worldwide is taking place in France, whose nuclear building program is exceeded only by that of the Soviet Union. How France has managed this remarkable achievement is well expressed in the words of the Director-General of EdF's Engineering and Construction Division (EdF, 1986, p. 3):

> The essential ingredient in the success of France's nuclear power program is the high level of competence of each sector involved in the program. Success also rests on government's, EDF's, and industry's determination to reach defined goals. The coordinated implementation of skills and resources has endowed our nuclear power industry with a unique degree of coherence that explains its ability to get things done.

Perhaps one of the reasons that France has embraced nuclear power with so little public dissent is the central role that French scientists have played in the development of nuclear physics. Henri Becquerel, Pierre and Marie Curie, Frédéric Joliot and others brought distinction to French nuclear science. Even so, this

distinguished history does not explain the French success. What also stands out is the organization that France has brought to the enterprise.

Key Components of the French Nuclear Power Program

Electricité de France is the world's largest electric utility, created in 1946 by the nationalization of more than 1,500 electricity producing and distributing companies. EdF generates 90% of France's electricity, owns all of the national transmission system and distributes 96% of the electricity. The utility designs, constructs, owns and operates its nuclear plants. EdF's electricity sales in 1986 amounted to 140 billion francs ($C 28 billion). It is France's largest investor, with 37 billion francs ($C 7.4 billion) invested in 1986.

The French nuclear industry is structured around two poles: the Commissariat à l'Énergie Atomique (French Atomic Energy Commission) and its subsidiaries on one hand and the major nuclear suppliers, led by Framatome and Alsthom, on the other.

The **Commissariat à l'Énergie Atomique** is a huge public company – with many subsidiaries and 40,000 employees – whose primary focus is nuclear research and development. CEA performs basic and applied research, develops military applications of atomic energy, is involved with all aspects of the nuclear fuel cycle including radioactive waste management, and provides assistance to the government in the fields of nuclear safety and security. COGEMA is CEA's largest subsidiary; its 14,000 employees supply the entire range of services associated with the nuclear fuel cycle. Also part of CEA is ANDRA – l'Agence Nationale pour la gestion des Déchets Radioactifs (National Radioactive Waste Management Agency). Since 1983, all of CEA's interests have been grouped in the holding company CEA-Industrie.

Framatome, established in 1958, designs and manufactures the main components of PWR reactors – pressure vessels, steam generators, pressurizers and in-core instrumentation. With its 5,000 employees, Framatome has performed the R&D and manufacturing of the nuclear steam supply systems for all three series of French PWRs. Framatome manufactures reactor fuel; carries out the supply, assembly, testing and commissioning of nuclear equipment; and performs reactor in-service inspections. Novatome, 70% owned by Framatome, built the Creys-Malville fast breeder reactor. Framatome also builds research reactors and nuclear propulsion reactors for submarines. In January of 1986, Framatome was reorganized and its new capital structure includes a 35% interest held by CEA-Industrie and a 10% interest held by EdF.

Alsthom is a group of companies employing 40,000 people and one of France's two largest heavy equipment manufacturers. One-third of Alsthom's activities are concentrated in the design and fabrication of electric power plant equipment; it is France's only manufacturer of turbo-generators.

Sources: EdF, 1986; Canada, External Affairs, Canadian Embassy, Paris, 1988; Framatome, 1987.

In 1946, the Commissariat à l'Énergie Atomique (CEA) assumed responsibility for promoting the use of nuclear energy in France. CEA's work resulted in three experimental power reactors being built at Marcoule. These reactors were the prototypes of the GGCR (natural uranium fuelled, graphite moderated, gas cooled) series. In 1956, the French Government asked EdF to build the first commercial

GGCRs, which took the form of the Chinon units A1, A2 and A3. The largest and last GGCR unit built in France was the 515 MWe (net) Bugey 1 reactor, which was connected to the grid in 1972. After development work on the enriched uranium, light water reactor design in the 1960s, France decided in 1969 to continue its nuclear program based on the PWR. (EdF, 1986)

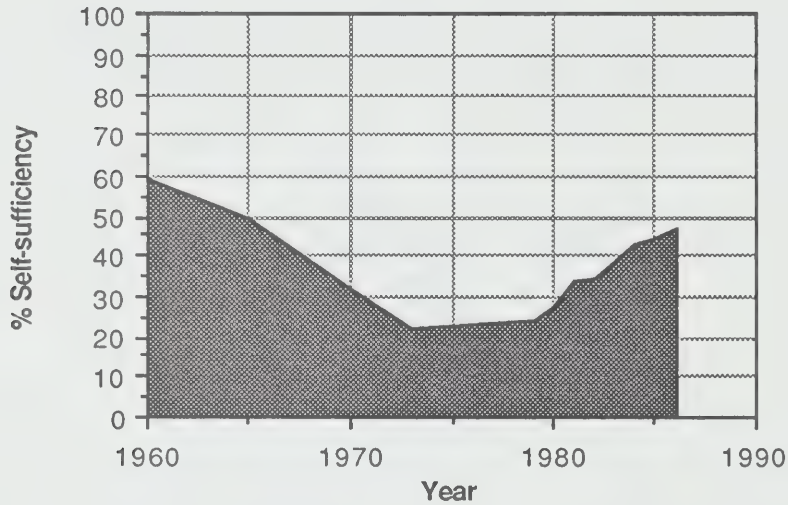
Having made this decision, the French Government undertook to establish a technically independent nuclear program. This process culminated in 1981 when the CEA acquired the Westinghouse interest in Framatome and terminated its licensing agreements with the American reactor manufacturer.

France also elected to design standardized reactor products, manufactured in series but adaptable to different sites. The result has been three groups of reactors: the 900 MW, 1,300 MW and 1,500 MW classes. To accommodate improvements in reactor technology, EdF has pursued a stepped evolution which has allowed for reactor sub-series within a class. These sub-series are distinguished by design improvements within the general class. Thus the 900 MW class has six "pre-series" reactors, 18 reactors of the "CP1" type and 10 reactors of the "CP2" type. All 34 reactors of the 900 MW class have entered service. In the 1,300 MW class, all 8 reactors of the "P4" type are in service and 4 of the 12 reactors of the "P'4" type had entered service by the end of 1987. Six reactors of the "N4" type in the 1,500 MW class are under construction. Six smaller reactors (four GGCRs, one PWR and one fast breeder) are also in service in France. During 1988, two 1,300 MW class reactors are expected to be connected to the national grid. (Framatome, 1988)

The first 900 MW reactor, Fessenheim 1, took 78 months to complete. Construction of the early CP1 units of the 900 MW class averaged about 70 months and later units were built in an average of 60 months. The 1,300 MW class reactors are taking from 72 to 80 months, from the start of civil works to grid connection, but the work schedule on some of these units is deliberately being stretched out because electricity demand has not grown as rapidly in recent years as had been forecast. (EdF, 1986)

In 1973, France obtained only 22.5% of its primary energy supply from domestic sources; in 1986, that share had risen to 46.2%, almost entirely due to the expansion of the nuclear power program. In the year 2000, France projects between 52% and 58% self-sufficiency in primary energy output. Figure 10 illustrates the change in France's energy self-sufficiency from 1960 to 1986. The decline in self-sufficiency from 1960 to 1973 reflects the substitution of imported oil for domestically produced coal in French energy use. Primary electricity represented 32.7% of France's consumption of primary energy in 1986 and nuclear-electricity accounted for 69.7% of the electricity used; therefore, nuclear-electricity comprised about 23% of French primary energy use. France projects that nuclear-electricity will satisfy 32% of its energy demand in 1990 (compared with 1.8% in 1973), oil 30% (66% in 1973), coal 15% (17.2% in 1973), natural gas 12% (8.4% in 1973), hydro-electricity 8% (5.5% in 1973) and renewable energy forms 3% (1.1% in 1973).

Figure 10: French Self-sufficiency in Primary Energy, 1960–1986



Source: Observatoire de l'Énergie, France.

2. The Current Power Reactor Program

France had 53 power reactors in service with a net installed generating capacity of 44,133 MWe as of 1 January 1988. An additional 10 units are under construction and will add a further 13,410 MWe to France's nuclear-electric generating capacity. Six older, smaller units have been shut down.

Table 11 presents information on France's operating power reactors.

In 1987, nuclear-electric generation accounted for 69.8% of France's total production of electricity. This share has grown rapidly in the 1980s, as the following statistics for nuclear-electricity as a percentage of total electricity output show: 1986 – 69.7%; 1985 – 64.9%; 1984 – 58.7%; 1983 – 48.3%; and 1982 – 38.7%. No other country in the world has this level of reliance on fission power in its domestic electricity system, and France projects that in 1990 three-quarters of its electricity (and almost one-third of the country's total requirement for primary energy) will be of nuclear origin.

Table 11: France's Operating Power Reactors at 1 January 1988

Reactor Unit / Type	In Operation	Net Electrical Output	Contractor
Chinon A-3 / GGCR	1967	480 MW	Industrie France
Chinon B-1 / PWR	1984	870 MW	Framatome
Chinon B-2 / PWR	1984	870 MW	Framatome
Chinon B-3 / PWR	1987	870 MW	Framatome
Chinon B-4 / PWR	1988	890 MW	Framatome
St-Laurent A-1 / GGCR	1969	480 MW	Industrie France
St-Laurent A-2 / GGCR	1971	515 MW	Industrie France
St-Laurent B-1 / PWR	1983	880 MW	Framatome
St-Laurent B-2 / PWR	1983	880 MW	Framatome
Chooz A-1 / PWR	1970	305 MW	A-F-W
Bugey-1 / GGCR	1972	540 MW	Industrie France
Bugey-2 / PWR	1979	920 MW	Framatome
Bugey-3 / PWR	1979	920 MW	Framatome
Bugey-4 / PWR	1979	900 MW	Framatome
Bugey-5 / PWR	1980	900 MW	Framatome
Phénix / FBR	1974	233 MW	Industrie France
Fessenheim-1 / PWR	1977	880 MW	Framatome
Fessenheim-2 / PWR	1978	880 MW	Framatome
Dampierre-1 / PWR	1980	890 MW	Framatome
Dampierre-2 / PWR	1981	890 MW	Framatome
Dampierre-3 / PWR	1981	890 MW	Framatome
Dampierre-4 / PWR	1981	890 MW	Framatome
Gravelines B-1 / PWR	1980	910 MW	Framatome
Gravelines B-2 / PWR	1980	910 MW	Framatome
Gravelines B-3 / PWR	1981	910 MW	Framatome
Gravelines B-4 / PWR	1981	910 MW	Framatome
Gravelines C-5 / PWR	1985	910 MW	Framatome
Gravelines C-6 / PWR	1985	910 MW	Framatome
Tricastin-1 / PWR	1980	915 MW	Framatome
Tricastin-2 / PWR	1980	915 MW	Framatome
Tricastin-3 / PWR	1981	915 MW	Framatome
Tricastin-4 / PWR	1981	915 MW	Framatome

Table 11 Continues...

Table 11 Continued **(France's Operating Power Reactors at 1 January 1988)**

Reactor Unit / Type	In Operation	Net Electrical Output	Contractor
Blayais-1 / PWR	1981	910 MW	Framatome
Blayais-2 / PWR	1983	910 MW	Framatome
Blayais-3 / PWR	1983	910 MW	Framatome
Blayais-4 / PWR	1983	910 MW	Framatome
Cruas Meysse-1 / PWR	1984	880 MW	Framatome
Cruas Meysse-3 / PWR	1984	880 MW	Framatome
Cruas Meysse-2 / PWR	1985	900 MW	Framatome
Cruas Meysse-4 / PWR	1985	880 MW	Framatome
Paluel-1 / PWR	1985	1,330 MW	Framatome
Paluel-2 / PWR	1985	1,330 MW	Framatome
Paluel-3 / PWR	1986	1,330 MW	Framatome
Paluel-4 / PWR	1986	1,330 MW	Framatome
Saint Alban-1 / PWR	1986	1,335 MW	Framatome
Saint Alban-2 / PWR	1987	1,335 MW	Framatome
Flamanville-1 / PWR	1986	1,330 MW	Framatome
Flamanville-2 / PWR	1987	1,330 MW	Framatome
Cattenom-1 / PWR	1987	1,300 MW	Framatome
Cattenom-2 / PWR	1987	1,300 MW	Framatome
Belleville-1 / PWR	1987	1,310 MW	Framatome
Nogent-1 / PWR	1987	1,310 MW	Framatome
Super-Phénix / FBR	1987	1,200 MW	Novatome

Source: France, Commissariat à l'Énergie Atomique, *Les Centrales Nucléaires dans le Monde*, 1987 Edition, Paris, 1987, p. 22-23; France, Commissariat à l'Énergie Atomique, *Dossier France au 1er janvier 1988*, CEA/DPg–E/88-53/JCLR, Paris, 1988.

Nuclear generating capacity already exceeds the base load and many of the 900 MW reactors are cycled to meet peaking power needs. Load following is most commonly required in May and June. In 1985, there were 935 daily cyclings by the 900 MW class reactors. During the peak month of June, there were more than 200 cyclings, with the 900 MW reactors running at less than 40% of capacity as a group during about 90 of those cyclings. (EdF, 1986) Some concern has been expressed about the stresses imposed on a reactor whose power level fluctuates on a frequent basis, but the French have no evidence to suggest that load following is prematurely aging these reactors.

Despite this less than optimal use of some of their reactors, the French claim a distinct cost advantage for nuclear-electricity. In 1985, 1 kilowatt-hour of nuclear-electricity cost 0.180 francs to produce while 1 kWh of coal-fired electricity cost 0.405 francs, more than twice as much. EdF asserts that "the French kWh is the cheapest in Europe." For a French power plant going into operation in 1992, EdF projects that the cost per kWh at a coal-fired station will be more than 150% of the cost at a nuclear station. (EdF, 1986)

Framatome has established an impressive record since the mid-1970s. Within France, the company built thirty-four 900-megawatt units from 1977 through 1987 and twelve 1,300-megawatt units from 1984 through 1987. Abroad, Framatome constructed five 900-megawatt units from 1975 through 1985. This totals 51 reactors in just 13 years, or an average of almost four units per year. Ten 1,300- and 1,500-megawatt units will be completed in France from 1988 through 1993, and four units will be completed abroad within the same period of time. The foreign sales have been to Belgium (three units operating and one under construction); South Africa (two units operating); South Korea (two units under construction); and China (two units under construction). (Framatome, 1988)

The remaining reactors under construction mark the end of France's intensive phase of reactor development. With reduced rates of load growth, reactor orders may fall to as few as one every 18 to 24 months. The French Government has committed itself, however, to providing whatever support is required to sustain domestic reactor manufacturing capability through this period of reduced activity. Continuing maintenance work on France's operating reactors, together with any reactor sales generated domestically or abroad, will be sufficient to sustain an essential level of activity. Framatome will intensify its work on improved unit performance, higher unit availability, safety enhancement and improved instrumentation and control systems. Framatome is also studying reactor life extension programs; officially, French reactors are designed for 40 years of operation but may be able to remain in service longer. Framatome observed that it builds reactor pressure vessels with about one-third as many welds as American-built pressure vessels. Therefore the French-made pressure vessels will suffer less embrittlement over time and should have a greater life expectancy.

Framatome will also diversify into non-nuclear fields, such as computer-based industrial systems, work on compressors and turbines, and special equipment and services in space and military applications of high technology. Another initiative is to fashion accords with foreign partners. For example, Framatome has an agreement with Babcock & Wilcox to market PWR fuel assemblies in North America; has entered into a joint study with KWU on the feasibility of introducing nuclear power in Indonesia; and, together with EdF and Westinghouse, is developing computer-aided training and systems services.

The French Government intends that Framatome will survive the temporary slump in reactor construction, whatever is required.

An objective of the CEA, arising from France's determination to be more independent in its energy system, has been complete control of the nuclear fuel cycle. This has been achieved. Uranium is produced by COGEMA, which controls two-thirds of France's reserves of this metal and produces 80% of the uranium mined in France. In the non-Communist world, COGEMA has access to more than 20% of uranium reserves. Through direct participation or acting through affiliates and subsidiaries, COGEMA has acquired uranium interests in such countries as Canada, the United States, Spain, Gabon, Niger, Zambia and Senegal. In Canada, COGEMA is the principal shareholder in Amok Ltd. (with a 38% direct interest and, through its 100% ownership of Compagnie de Mokta, a further 37% interest), mining at Cluff Lake in Saskatchewan, and holds a 36.4% interest in Cigar Lake Mining Corp., a joint venture with Saskatchewan Mining Development Corporation and Idemitsu. In 1986, COGEMA produced 7,700 tonnes of uranium concentrates, including 2,600 tonnes from its French mines. (Canada, External Affairs, Canadian Embassy, Paris, 1988; France, CEA, 1987)

Ore conversion into uranium metal and uranium hexafluoride is done by Comurhex, 49% owned by COGEMA. France's refining and conversion capacity is approximately 25,500 tonnes of uranium per year, or 25% of the non-Communist world's capacity. Its share of the market is roughly the same. France's uranium enrichment capacity is 11.4 million swu (isotope separative work units) [1] per year, out of a world capacity, including the Communist bloc, of 32.1 million swu/year. The great bulk of this capacity – 10.8 million swu/year – is represented by the Eurodif plant at Tricastin, the world's largest uranium enrichment complex. COGEMA holds a 51.5% interest in Eurodif, with Italy, Spain and Belgium being the other participants. Eurodif can supply the fuel for about ninety 1,000 MW reactors on a continuing basis. Eurodif currently holds about 43% of the global market for uranium enrichment. (NEI, 1988; Personal communication: CEA, 14 April 1988)

COGEMA is similarly involved in the business of fuel fabrication. Fuel for the GGCRs and fast breeder reactors is manufactured by SICN (Société Industrielle de Combustible Nucléaire), a wholly-owned subsidiary of COGEMA. Fragema, owned equally by COGEMA and Framatome, markets LWR fuel which is made by FBFC, owned 25% by COGEMA, 25% by Framatome and 50% by Uranium Péchiney. The fabrication of mixed-oxide (uranium-plutonium) fuels is done by Commox, owned 60% by COGEMA and 40% by Belgonucléaire. France has developed the capacity to manufacture about 1,550 tonnes of heavy metal (uranium and plutonium) fuel per year, and claims approximately 19% of the market. (Canada, External Affairs, Canadian Embassy, Paris, 1988; France, CEA, 1987; Personal communication: CEA, 14 April 1988)

---

(1) The separative work unit is a measure of the effort expended in separating uranium into two streams, one enriched and the other depleted. The separative work unit is independent of the separation process applied. The kilogram is the unit of separative work, and enrichment charges and energy consumption are calculated per kilogram of separative work performed.

The reprocessing of spent fuel is carried out in COGEMA plants at Marcoule and La Hague. La Hague is undergoing a major expansion which will boost its reprocessing capability from 400 tonnes of heavy metal/year to 1,600 tonnes. Marcoule has a capacity of 600 tonnes/year. One of the new 800 tonnes/year reprocessing plants at La Hague is dedicating the first 10 years of its operation to 30 foreign customers of COGEMA who signed reprocessing contracts and financed its construction.

3. Radioactive Waste Management

ANDRA, the National Radioactive Waste Management Agency, is a non-profit government agency established in 1979 by ministerial decree within the CEA. It is responsible for the long-term management of all types of radioactive wastes from all sources. ANDRA reflects the decision by the French Government to separate radioactive waste management from regulatory and inspection activities.

ANDRA has two responsibilities: (1) to manage existing disposal sites of which there is one at Centre de la Manche on the Cotentin Peninsula; and (2) to design, site and construct new long-term facilities. Funding to cover the costs of these activities including transportation of radioactive wastes to the facilties comes directly from the waste producers, particularly EdF but also research laboratories, hospitals, universities and industry. No public funds are used for waste management. ANDRA notes that, in 1982, radioactive wastes were being created in France at the rate of 1 kg per capita annually, while all other domestic and industrial wastes were being generated at the rate of 2,500 kg per capita annually (France, CEA, ANDRA, undated).

Radioactive wastes are divided into two categories for disposal. Short-lived wastes are those radioactive materials having a half-life of up to 30 years. After 300 years (ten times the longest half-life of any radionuclide in this group), the residual radiological risk at the disposal facility will be so low that the site can be put to unrestricted use. Short-lived wastes are therefore adequately cared for in the French view by near-surface disposal. Long-lived wastes, whether low-, intermediate- or high-level, must be kept from the population for thousands of years and are therefore to be disposed of through deep burial (several hundred metres) in stable geological formations.

Near-surface disposal of short-term wastes is based on three levels of protection: site selection, facility design and waste packaging. The objective is to prevent the radioactive materials from being transported away from the site by water. At Centre de la Manche, much of the waste is enclosed in drums. These drums stand freely if their contents are low-level wastes; they are encased in concrete monoliths if their contents are higher-level wastes. There is a system for monitoring the level of radioactivity within the facility and inspection galleries are part of its design. Begun in 1969, Centre de la Manche was taken over by ANDRA in 1979. This facility has a capacity of 485,000 cubic metres; to mid-1986, 350,000 cubic metres of wastes had

been emplaced. With wastes being added at the rate of approximately 30,000 cubic metres annually, Centre de la Manche will be filled in 1991. The site for a new facility has been selected about 250 km from Paris and permission to construct a repository was granted in 1987. This facility, known as Centre de l'Aubé, will have a capacity of one million cubic metres and be adequate for about 30 years. It is scheduled to begin commercial operation in late 1990 or early 1991. To stabilize the generation of lower-level, short-lived wastes at roughly 30,000 cubic metres per year, France's nuclear power stations have begun a major program to decrease waste production.

The second element of ANDRA's activities is long-lived radioactive waste disposal. When the second reprocessing unit at La Hague becomes operational, about 4,000 to 5,000 cubic metres of long-lived wastes will be generated yearly. By the year 2000, accumulated wastes will amount to approximately 60,000 cubic metres. ANDRA is currently engaged in a site research program to select an appropriate location for a disposal facility. Granite, salt, clay and shale are all considered suitable geological formations for disposal and France has a research site in each of these four types. A program was begun in 1987 to confirm a single site; that process is expected to be finished in 1990. The next step will be to construct a full-fledged laboratory to qualify the site, with site validation anticipated around 1995. Facility construction could be completed by very early in the next century, although ANDRA suspects that this schedule may not be met.

The French regard radioactive waste management as a *technical* problem; it is not an issue whose solution is to be determined by a referendum or by protest. Unlike the situation in Sweden and West Germany, local governments in France have no right to refuse a site selected by ANDRA for a disposal facility. To date there has not been any significant problem with public acceptance of the waste management program, in part because ANDRA undertakes a major public information program to explain its activities. The public is said to be strongly opposed, however, to the notion of accepting radioactive wastes from other countries.

E. The U.S. Nuclear Power Program

1. History of American Nuclear Development

The first demonstration of a sustained fission chain reaction was accomplished by Enrico Fermi, under the stands of Stagg Field at the University of Chicago. Fermi built a graphite-moderated natural uranium "pile" operating at very low power so that it could be cooled in the open air. This pile went critical on December 2, 1942, and was immediately followed by the construction of larger piles at Hanford in Washington State, with the intention of producing plutonium for an atomic bomb.

Congress subsequently passed the *Atomic Energy Act* of 1946, which dealt with the continued military development of nuclear energy while establishing a legal

framework for industrial applications. This Act created the Atomic Energy Commission (AEC) and provided it with oversight authority for U.S. nuclear activities. In 1954, Congress approved a program to build five industrial prototype reactors. These included an experimental boiling water reactor at the Argonne National Laboratory near Chicago; a graphite-moderated sodium-cooled reactor at Santa Susanna in California; a heavy water reactor at Oak Ridge, Tennessee; an experimental breeder reactor at Idaho Falls; and the 60 MW Shippingport prototype PWR reactor which began operation in 1957. Shippingport became the first civilian power reactor in the United States, and was built by Westinghouse under contract for the AEC. It remained in service as a power reactor until 1974, ending its life as a test reactor before being decommissioned in 1982.

With the assistance of the AEC, private companies took up civilian reactor construction. After Shippingport, Westinghouse constructed the 185 MW Yankee Rowe PWR in Massachusetts, which entered service in 1961. Babcock & Wilcox built the 265 MW Indian Point 1 reactor near New York City, continuing the evolution of the PWR design. General Electric opted for the BWR design path, building the 200 MW Dresden 1 reactor in Illinois for Commonwealth Edison. From this auspicious beginning, the U.S. nuclear industry was to grow rapidly through the 1960s and 1970s.

The accident at unit 2 of the Three Mile Island nuclear power station near Harrisburg, Pennsylvania on March 28, 1979 was a major setback to the U.S. nuclear program. The plant was extensively damaged and radioactivity was released to the environment. The average radiation dose delivered to an individual living within a five-mile radius of the plant was calculated to be about 10% of the annual background radiation, and the maximum exposure to an off-site individual in the general population was estimated at 70 millirems. [This level of exposure is roughly half of what an average person would be exposed to over the course of a year from natural sources, medical sources, etc.] Exposure of the general public to radioactivity was so small that it was concluded that there would be no detectable increase in the cancer rate, developmental abnormalities or genetic effects. Nonetheless, the accident had a profound impact. As the 1979 *Report of The President's Commission on the Accident at Three Mile Island* observed (page 2):

> ...The accident was initiated by mechanical malfunctions in the plant and made much worse by a combination of human errors in responding to it...During the next 4 days, the extent and gravity of the accident was unclear to the managers of the plant, to federal and state officials, and to the general public. What is quite clear is that its impact, nationally and internationally, has raised serious concerns about the safety of nuclear power...

The Commission stated that its findings did not require drawing the conclusion that nuclear power is inherently too dangerous to be exploited, but did observe that "fundamental changes are necessary if those risks [associated with nuclear power] are to be kept within tolerable limits". The Commission concluded that people-related problems were the fundamental issue, not equipment problems.

> When we say that the basic problems are people-related, we do not mean to limit this term to shortcomings of individual human beings – although those do exist. We mean more generally that our investigation has revealed problems with the "system" that manufactures, operates, and regulates nuclear power plants. There are structural problems in the various organizations, there are deficiencies in various processes, and there is a lack of communication among key individuals and groups...
>
> We note a preoccupation with regulations. It is, of course, the responsibility of the Nuclear Regulatory Commission to issue regulations to assure the safety of nuclear power plants. However, we are convinced that regulations alone cannot assure safety. Indeed, once regulations become as voluminous and complex as those regulations now in place, they can serve as a negative factor in nuclear safety. The regulations are so complex that immense efforts are required by the utility, by its suppliers, and by the NRC to assure that regulations are complied with...
>
> The most serious "mindset" is the preoccupation of everyone with the safety of equipment, resulting in the down-playing of the importance of the human element in nuclear power generation. We are tempted to say that while an enormous effort was expended to assure that safety-related equipment functioned as well as possible, and that there was backup equipment in depth, what the NRC and the industry have failed to recognize sufficiently is that the human beings who manage and operate the plants constitute an important safety system. (United States, The President's Commission on the Accident at Three Mile Island,1979, p. 8-10)

It is the Committee's impression that many of these systemic problems persist in the U.S. nuclear power program.

The United States terminated its main work on breeder reactors when Congress voted to end support of the 350 MW Clinch River, Tennessee breeder project. Begun in 1973, Clinch River had absorbed nearly $US 2 billion when the project was stopped.

The expansion of U.S. nuclear generating capacity since the 1973 oil embargo is calculated to have displaced more than 3.5 billion barrels of imported oil at a saving estimated to approach $US 100 billion. The corresponding capital investment in this expanded nuclear-electric generating capacity amounted to $US 130 billion. In 1973, nuclear-electricity stood fifth in the United States among the various sources of electric power production. Nuclear power overtook oil-fired generation in 1980, gas-fired generation in 1983 and hydro-electric generation in 1984. Today, nuclear power stands second only to coal-fired generation.

Although total energy consumption in the United States in 1986 was up by only about 2% from the level of 1973, the demand for electricity had increased by more than 40% while the demand for non-electric energy had fallen by approximately 11%.

To the end of 1987, 13 state referenda had been held to shut down operating power reactors or to prevent the operation of reactors under construction. All 13 referenda had been defeated. Seven votes were held in 1976; two have been conducted since the Chernobyl accident. Three attempts to shut down Maine's one

operating power reactor, Maine Yankee, failed by margins of 60-40 (1980), 55-45 (1982) and 59-41 (1987). Maine Yankee has produced electricity for 15 years at an average operating cost of 2.5 cents/kWh, one of the lowest unit costs in the world. (USCEA, 1988b) At least three attempts will be made to shut down operating power reactors during 1988 (in California, Oregon and Massachusetts).

2. The Current Power Reactor Program

The United States has the world's largest nuclear-electric power program. At January 1, 1988, there were 109 operable reactors totalling 97.2 GW of generating capacity, 14% of the nation's total electrical generating capacity. These units supplied approximately 18% of the electricity generated in the United States during 1987. Thirty-three of the 50 states have licensed power reactors, led by Illinois with 13 units. Fourteen reactors with an aggregate capacity of 16.6 GW are under construction and two reactors with a capacity of 2.2 GW are on order. Four states (Vermont, Connecticut, New Jersey and South Carolina) derive more than 50% of their electricity from nuclear generation, with Vermont leading at 76% in 1987. An additional 12 states obtain more than 25% of their electricity from nuclear stations. (USCEA, 1988a) Table 12 lists operable power reactors by state, as of January 1, 1988.

The PWR design has dominated the U.S. program, with twice the installed capacity of the BWR type (65,299 MW of PWR capacity compared with 33,802 MW of BWR capacity, as of July 1987). With the exception of two BWR units, all of the reactor capacity under construction in the United States today is of PWR design. (NEI, 1988, p. 13)

Although this world-leading program is an impressive accomplishment in the country that originated the LWR technology, the statistics obscure the fact that the U.S. nuclear power program is in disarray today. Not a single new unit is planned in the United States, and the most recently-placed reactor order, after reactor cancellations are excluded, dates back to October of 1973. Thus every remaining reactor under construction in the United States is 15 years or more old. It was made clear to the Committee in its U.S. discussions that no new reactor orders will be placed as long as the current conditions prevail.

The average U.S. electrical generating station is now 19 years old. Although life-extension programs are underway at many of these stations, both fossil-fuelled and nuclear, the growing age of American electric capacity is causing some erosion in generating efficiency. Coupled with the lack of new generating capacity, problems in electric power reliability will soon emerge and, in fact, are already becoming apparent in New England. The New England Power Pool had to institute voltage reductions on three occasions in 1987 while two completed nuclear plants in or adjoining the region – Shoreham on Long Island, New York and Seabrook in Vermont – sit idle. [Seabrook is authorized to load fuel but not permitted to operate, and remains in the construction permit category although 100% complete.]

Table 12: Operating Power Reactors in the United States as of 1 January 1988

State	Reactor Unit / Type	Commercial Operation	Net Electrical Output (MW)	Manufacturer
Alabama	Joseph M. Farley 1-2 / PWR	77/81	829/829	Westinghouse
	Browns Ferry 1-3 / BWR	74/75/77	1065/1065/1065	General Electric
Arizona	Palo Verde 1-3 / PWR	86/86/88	1270/1270/1270	Combustion Engineering
Arkansas	Arkansas Nuclear 1-2 / PWR	74/80	850/912	Babcock & Wilcox
California	Diablo Canyon 1-2 / PWR	85/86	1084/1106	Westinghouse
	Rancho Seco 1 / PWR	75	918	Babcock & Wilcox
	San Onofre 1 / PWR	68	436	Westinghouse
	San Onofre 2-3 / PWR	83/84	1070/1080	Combustion Engineering
Colorado	Fort St. Vrain / HTGR	79	330	General Atomic
Connecticut	Haddam Neck / PWR	68	582	Westinghouse
	Millstone 1 / BWR	70	660	General Electric
	Millstone 2 / PWR	75	870	Combustion Engineering
	Millstone 3 / PWR	86	1153	Westinghouse
Florida	Crystal River 3 / PWR	77	850	Babcock & Wilcox
	Turkey Point 3-4 / PWR	72/73	666/666	Westinghouse
	St. Lucie 1-2 / PWR	76/83	839/839	Combustion Engineering
Georgia	Edwin I. Hatch 1-2 / BWR	75/79	775/781	General Electric
	Alvin W. Vogtle 1 / PWR	87	1122	Westinghouse
Illinois	Dresden 2-3 / BWR	70/71	794/794	General Electric
	Zion 1-2 / PWR	73/74	1040/1040	Westinghouse
	Quad Cities 1-2 / BWR	72/72	789/789	General Electric
	LaSalle 1-2 / BWR	84/84	1078/1078	General Electric
	Braidwood 1-2 / PWR	88/88	1120/1120	Westinghouse
	Byron 1-2 / PWR	85/87	1120/1120	Westinghouse
	Clinton 1 / BWR	87	933	General Electric
Iowa	Duane Arnold / BWR	75	565	General Electric
Kansas	Wolf Creek / PWR	85	1150	Westinghouse
Louisiana	River Bend 1 / BWR	86	940	General Electric
	Waterford 3 / PWR	85	1104	Combustion Engineering
Maine	Maine Yankee / PWR	72	825	Combustion Engineering
Maryland	Calvert Cliffs 1-2 / PWR	75/77	825/825	Combustion Engineering
Massachusetts	Pilgrim 1 / BWR	72	670	General Electric
	Yankee / PWR	61	175	Westinghouse

Table 12 continues...

Table 12 Continued (Operating Power Reactors in the United States as of 1 January 1988)

State	Reactor Unit / Type	Commercial Operation	Net Electrical Output (MW)	Manufacturer
Michigan	Big Rock Point / BWR	65	69	General Electric
	Palisades / PWR	71	777	Combustion Engineering
	Fermi 2 / BWR	88	1100	General Electric
	Donald C. Cook 1-2 / PWR	75/78	1030/1100	Westinghouse
Minnesota	Monticello / BWR	71	545	General Electric
	Prairie Island 1-2 / PWR	73/74	530/530	Westinghouse
Mississippi	Grand Gulf 1 / BWR	85	1250	General Electric
Missouri	Callaway / PWR	84	1120	Westinghouse
Nebraska	Cooper / BWR	74	760	General Electric
	Fort Calhoun 1 / PWR	73	492	Combustion Engineering
New Jersey	Oyster Creek / BWR	69	650	General Electric
	Salem 1-2 / PWR	77/81	1106/1106	Westinghouse
	Hope Creek 1 / BWR	86	1067	General Electric
New York	Indian Point 2-3 / PWR	73/76	873/965	Westinghouse
	James A. FitzPatrick / BWR	75	816	General Electric
	Shoreham / BWR	(a)	809	General Electric
	Nine Mile Point 1-2 / BWR	69/88	610/1080	General Electric
	Robert E. Ginna / PWR	70	470	Westinghouse
North Carolina	Brunswick 1-2 / BWR	77/75	821/821	General Electric
	Shearon Harris 1 / PWR	87	900	Westinghouse
	William McGuire 1-2 / PWR	81/84	1129/1129	Westinghouse
Ohio	Perry 1 / BWR	87	1205	General Electric
	Davis-Besse 1 / PWR	77	860	Babcock & Wilcox
Oregon	Trojan / PWR	76	1130	Westinghouse
Pennsylvania	Beaver Valley 1-2 / PWR	76/87	833/836	Westinghouse
	Three Mile Island 1-2 / PWR	74/78 (b)	819/900	Babcock & Wilcox
	Susquehanna 1-2 / BWR	83/85	1050/1050	General Electric
	Peach Bottom 2-3 / BWR	74/86	1065/1065	General Electric
	Limerick 1 / BWR	86	1055	General Electric
South Carolina	H.B. Robinson 2 / PWR	71	700	Westinghouse
	Oconee 1-3 / PWR	73/74/74	846/846/846	Babcock & Wilcox
	Catawba 1-2 / PWR	85/86	1129/1129	Westinghouse
	Summer 1 / PWR	84	885	Westinghouse
Tennessee	Sequoyah 1-2 / PWR	81/82	1148/1148	Westinghouse

Table 12 continues...

Table 12 Continued (Operating Power Reactors in the United States as of 1 January 1988)

State	Reactor Unit / Type	Commercial Operation	Net Electrical Output (MW)	Manufacturer
Texas	South Texas Project 1 / PWR	88	1250	Westinghouse
Vermont	Vermont Yankee / BWR	72	528	General Electric
Virginia	Surry 1-2 / PWR	72/73	781/781	Westinghouse
	North Anna 1-2 / PWR	78/80	926/926	Westinghouse
Washington	WPPSS 2 / BWR	84	1100	General Electric
Wisconsin	Point Beach 1-2 / PWR	70/72	485/485	Westinghouse
	Kewaunee / PWR	74	535	Westinghouse

Notes: Reactors shown as beginning commercial operation in 1988 hold low power or full power licences issued before the end of 1987.

(a) The Shoreham reactor received a nonrestricted low power operating licence on July 3, 1985, but has not been allowed to enter commercial service.

(b) Three Mile Island 2 has been shut down since the accident of March 28, 1979, and is not included as a licensed reactor. Three Mile Island 1 was shut down on March 28, 1979, and allowed to resume commercial operation on November 8, 1985.

Source: U.S. Council for Energy Awareness, *Electricity from Nuclear Energy*, 1988 Edition, Washington, D.C., 1988a, p. 9-19.

State Public Utility Commissions are increasingly unwilling to allow the full cost of completed nuclear stations (and some coal-fired stations) be included in the rate base. Over the period 1980-1986, state regulators made the following disallowances for new power reactors coming into service (values are given in U.S. funds and the year of commercial operation is shown in brackets) ("Disallowances by State Regulators for Nuclear Units (1980-1986)", *Nuclear Industry*, March/April 1988, p. 64):

Wolf Creek 1 (Kansas/1985) –	$1,641.0 million
Waterford 3 (Louisiana/1985) –	$284.0 million
Summer 1 (South Carolina/1984) –	$123.0 million
Susquehanna 1 (Pennsylvania/1983) –	$287.0 million
Susquehanna 2 (Pennsylvania/1985) –	$560.0 million
Shoreham 1 (New York/no commercial service) –	$1,395.0 million

San Onofre 2 & 3 (California/1983 and 1984) –	$328.0 million
Millstone 3 (Connecticut/1986) –	$353.0 million
Limerick 1 (Pennsylvania/1986) –	$368.9 million
Grand Gulf 1 (Mississippi/1985) –	$49.0 million
Fermi 2 (Michigan/1988/1985 full power operating licence) –	$680.0 million
Callaway 1 (Missouri/1984) –	$421.7 million
Byron 1 (Illinois/1985) –	$101.5 million

These disallowances may change in amount as regulatory decisions are appealed and court settlements occur. Most U.S. utilities are privately owned and it is the stockholders who ultimately shoulder this penalty; they are understandably reluctant to underwrite new investments in nuclear power.

The cost of nuclear-electricity is a subject of debate in the United States. Earlier nuclear stations have a clear cost advantage over oil-fired plants. Science Concepts of Washington, in research funded by the U.S. Council for Energy Awareness, calculates that the life-cycle cost of nuclear-electricity averaged over all nuclear units completed through 1987 amounts to 4.7¢/kWh compared with oil-fired electricity at 8.2¢/kWh (low oil price scenario), 9.7¢/kWh (base case for future oil prices), or 11.4¢/kWh (high oil price scenario). If the subgroup of the most expensive nuclear stations – those completed from 1984 through 1987 – is considered, Science Concepts finds their life-cycle cost to be marginally below the low oil price scenario, at 7.6¢/kWh. Given the large "front loading" effect caused by absorbing the capital cost of a reactor into the rate base, the first-year cost of nuclear-electricity from the high-cost recent reactors is calculated to be 60% higher than the first-year cost of oil-fired electricity but to be 20% below the life-cycle cost of the oil-fired electricity in the U.S. Department of Energy (DOE) oil price base case. The life-cycle of a nuclear or oil-fired generating unit is taken to be 30 years. The oil price projections used were those of the DOE. The low price scenario has oil costing $US 27.83 per barrel in constant 1987 dollars in the year 2000; the base case has oil costing $US 34.18 in 2000; and the high price scenario has oil at $US 43 at the end of the century. In the high price case, the cost of oil is projected to fall to $US 30 (in constant 1987 dollars) in 2010, as substitutes for oil reduce demand. (Lennox and Mills, 1988a)

DOE's Energy Information Administration (EIA) has released a study of nuclear power plant operating costs in the United States. Its findings are not comforting for the U.S. nuclear industry. The question that the EIA attempted to answer was: What factors caused the escalation in nonfuel operating costs of power reactors over the period 1975-1984? The analysis considered operating and maintenance (O&M) costs and the cost of post-operational capital additions. The study did not identify all of the factors contributing to the escalation in the cost of nuclear-electricity nor did it disaggregate all of the costs, but did reach a number of conclusions. (United States, DOE, EIA, 1988)

The principal factors contributing to increased O&M costs were determined to be: (a) real effects of rising O&M wage rates, the price of O&M materials, lagged O&M costs and simple inflation; (b) increased regulatory requirements by the Nuclear Regulatory Commission (NRC); and (c) increases in the cost of replacement power. Increasing age and reactor operating experience reduced O&M costs, and O&M costs tended to fall as the price of reactor capital additions rose. Some states have introduced incentive rate-of-return programs (rewarding utilities with a higher rate of return if their nuclear plants perform well and penalizing them if the units do not) which were found to increase O&M costs. The rising costs of post-operational capital additions were primarily a function of: (a) increased regulatory requirements by the NRC; (b) unexplained costs; (c) increasing age; and (d) the replacement of steam generators and pipe cracking repairs. Past maintenance practices, as measured by average real O&M costs in previous years, reduce capital additions costs as maintenance expenditures rise. The effect of state regulatory factors on capital additions costs could not be determined. (United States, DOE, EIA, 1988)

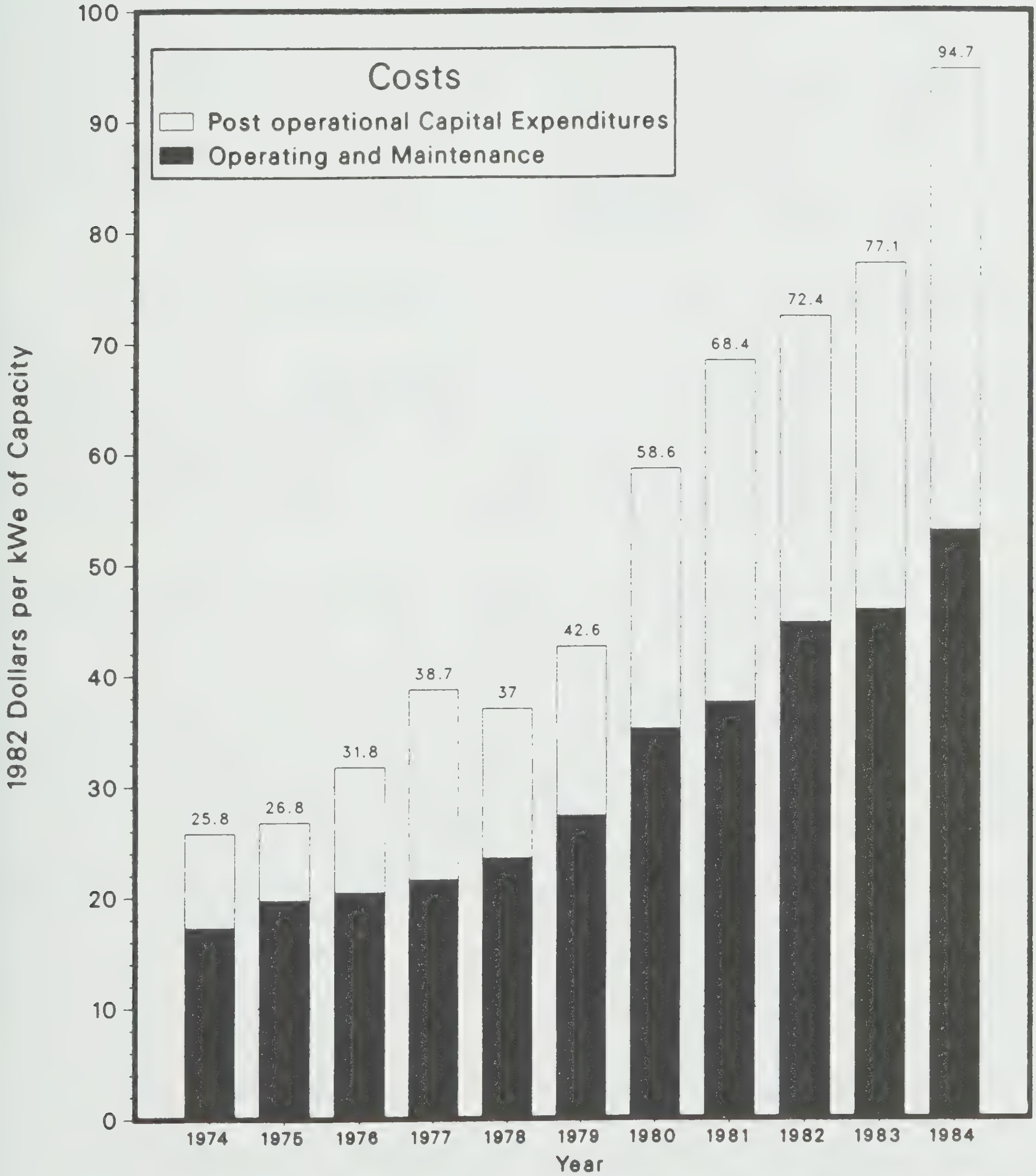
Plant aging has a dual effect: operating experience tends to reduce costs while plant deterioration tends to increase costs. For O&M costs, the learning effect was found to outweigh the aging effect. For post-operational costs of capital additions, however, the aging effect outweighs the learning effect. Since the study was restricted to nuclear reactors of 400 MW capacity or greater, the average plant age was only eight years; DOE cautions against drawing firm conclusions about the future trend in O&M costs as a function of plant aging based on this limited experience. (United States, DOE, EIA, 1988)

Figure 11 displays the escalation in annual, real, nonfuel operating costs of U.S. power reactors over the 11-year period 1974-1984. Costs are subdivided into post-operational capital expenditures and operating and maintenance expenditures, and are expressed in constant 1982 dollars.

The EIA estimates that routine operating and maintenance expenses, measured in 1982 dollars, rose from $US 17 per kilowatt of installed electrical generating capacity in 1974 to $US 53 per kilowatt in 1984. This translates into an average annual increase of 12%. Post-operational capital investments rose from $US 9 per kilowatt of capacity to $US 42, an average annual increase of 17%. In contrast, the EIA reports that the real O&M costs at coal-fired plants increased at a rate of only 2% annually over the same period. This led the EIA to draw two conclusions.

> ...First, the continued escalation in operating costs may reduce or possibly even negate any cost advantage that nuclear power might have. Many analysts believe that the nuclear power plants that entered commercial operation in the 1960's and 1970's were economical relative to coal-fired power plants. This may not be the case if operating costs continue to escalate. Second, many proponents of nuclear power are currently assuming an expected licensed operating lifetime of nuclear power plants of more than 40 years. If operating costs continue to escalate, at some point in time it may be economical to shut down older plants, and thus the assumption of a 40-year operating life may be optimistic... (United States, DOE, EIA, 1988, p. 1)

Figure 11: Escalation in Annual, Real, Nonfuel Operating Costs for U.S. Reactors of 400 MW Capacity or Greater, 1974-1984



Source: United States, DOE, EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, *An Analysis of Nuclear Power Plant Operating Costs*, DOE/EIA–0511, Washington, D.C., 16 March 1988, p. viii.

The Nuclear Regulatory Commission regulates the civilian use of nuclear materials in the United States. Created by the *Energy Reorganization Act* of 1974, the NRC took over the regulatory functions of the former Atomic Energy Commission. The Energy Research and Development Administration (which was in turn to become part of the Department of Energy) assumed the other functions of the AEC. The NRC is headed by five Commissioners, who are appointed by the President for five-year terms, subject to Senate confirmation. With its 3,300 employeees and a budget that averages about $US 400 million annually, the NRC has 12.5 times the staff and more than 19 times the budget of its Canadian counterpart, the Atomic Energy Control Board. The U.S. civilian nuclear program is about eight times the generating capacity of the Canadian program. A more interesting comparison may be that the AECB has two lawyers on staff whereas the NRC has approximately 200.

The NRC has three basic functions, in addition to licensing the export and import of nuclear materials and equipment (United States, NRC, undated):

(1) The Commission licenses the construction and operation of nuclear power plants and other nuclear facilities. It licenses the possession and use of nuclear materials for medical, industrial, educational and research purposes. Regulatory authority for the licensing of nuclear materals has, however, been transferred to 29 states under the NRC's Agreement States Program.

(2) The Commission conducts inspections and investigations to ensure that licensed activities are conducted in compliance with regulations, and enforces compliance as required.

(3) The Commission is mandated by law to conduct an extensive regulatory research program in the areas of nuclear safety, safeguards and environmental assessment. Since the Three Mile Island accident, expenditures on regulatory research have averaged more than $US 100 million per year.

Three operating offices conduct the NRC's business. The Office of Nuclear Reactor Regulation evaluates applications to build and operate power reactors; inspects and licenses the construction and operation of power reactors; inspects and licenses the construction and operation of research and test reactors; and licenses reactor operators.

The Office of Nuclear Material Safety and Safeguards is responsible for licensing nuclear fuel cycle facilities; for licensing the possession and use of radioactive materials; for regulating the packaging of radioactive materials for transport; for developing policies to safeguard nuclear facilities and materials from theft, sabotage or diversion; and for reviewing the application of IAEA safeguards on U.S.-sourced nuclear materials used in foreign countries. This Office also directs the implementation of the Commission's responsibilities under the *Nuclear Waste Policy Act* of 1982; the *Low-Level Radioactive Waste Policy Act* of 1980 and the *Low-Level Radioactive Waste Policy Amendments Act* of 1985, which govern the disposal of

low-level wastes; and the *Uranium Mill Tailings Radiation Control Act* of 1978.

The Office of Nuclear Regulatory Research plans and implements programs of nuclear regulatory research; develops standards and resolves safety issues at regulated facilities; develops and promulgates technical regulations; and coordinates research activities inside and outside the Commission. (United States, NRC, 1987b)

When asked by the Committee why the NRC had developed such a highly prescriptive system of power reactor regulation, the Commission's Director, Harold Denton, observed that the 109 operable American power reactors represented at least 60 distinctly different design configurations. Standardization has not been been a goal of commercial reactor development in the United States.

Public liability is provided under the *Price-Anderson Act*, which established a system of private funds and government indemnity to pay public liability claims for personal injury and property damage arising from a nuclear accident. Any commercial nuclear power plant with a rated capacity of 100 MWe or more must carry liability coverage. A limited federal liability covers DOE (mostly defence-related) activities. The Act was passed in 1957 and has been twice extended for 10-year periods. The last extension carried forward to 31 July 1987 and Congress was considering the next extension at the time of the Committee's Washington visit.

Price-Anderson provides for two tiers of coverage. The first $US 160 million is made available from two private nuclear-liability insurance pools, American Nuclear Insurers and Mutual Atomic Energy Liability Underwriters. In the event of an accident causing damages exceeding $US 160 million, "each commercial nuclear power plant licensee would be assessed a prorated share of damages in excess of the primary insurance layer up to $5 million per reactor per year per incident but not in excess of $10 million for each reactor in any year" (United States, NRC, 1983, p. 1). Thus, under the last extension of Price-Anderson, the maximum liability per accident was approximately $US 700 million. Under the proposed amendments to Price-Anderson considered by Congress, it was generally agreed that the liability coverage should be raised to about $US 7 billion. In the House of Representatives version of Price-Anderson renewal, each power reactor licensee would become liable for damages up to $US 63 million per reactor per accident, to be paid into a claims fund at the rate of $US 10 million per year. The first tier of insurance would remain at $US 160 million. In the Senate version, each reactor would be assessed up to $US 12 million per year for a maximum of five years, giving a maximum coverage of approximately $US 6.6 billion with the current number of licensed reactors. Both bills provide for an inflation adjustment. Neither bill would extend liability to reactor manufacturers or other nuclear suppliers, even if the supplier is guilty of negligence or intentional violation of federal safety regulations. Part of the debate centred on whether the *Price-Anderson Act* should be renewed for 10 years (House version) or for 20 years (Senate version). (Price-Anderson Campaign, "Floor Vote Briefing Packet")

In August 1988, the House and Senate reached a compromise on Price-

Anderson renewal. The Act was extended for 15 years to 1 August 2002. The ceiling on liability was raised to approximately $US 7 billion and now applies both to NRC reactor licensees and to the facilities of DOE contractors. In the case of NRC licensees, damages would be paid from the insurance pool described above. In the case of an accident occurring at the nuclear facility of a DOE contractor, the federal government would pay the damages. If damages from a nuclear accident are expected to exceed $US 7 billion, the President must submit to Congress a compensation plan that includes an estimate of damages and recommendations for sources of funding to pay for damages exceeding the liability limit. In a new departure, the Act allows the Secretary of Energy to impose fines of up to $US 100,000 per day on contractors who violate DOE safety regulations. Contractors' employees become subject to criminal penalties for willful violation of safety rules. These civil penalties do not apply to DOE nuclear research laboratories (such as Los Alamos, Lawrence Livermore, Sandia and Brookhaven).

Critics of Price-Anderson note that the NRC proposed to Congress in 1983 that utility liability be unlimited, with a reactor licensee responsible for annual assessments of $US 10 million per year per reactor until all public damages arising from an accident are settled. Figure 11 indicates that non-fuel operating costs had already risen to $US 95 per kilowatt of installed capacity (measured in constant 1982 dollars) by 1984; a surcharge of $US 10 million per reactor per year in 1988 dollars added to today's operating costs would not represent a large increment in those costs and could be accommodated in the rate base if passed through to consumers. Critics also want nuclear suppliers and contractors subject to some degree of liability. A utility can sue a supplier for damages – as GPU Nuclear Corp. (a consortium of Metropolitan Edison, Jersey Central Power & Light and Pennsylvania Electric) did to reactor manufacturer Babcock & Wilcox for on-site damages at Three Mile Island – but the supplier need not purchase liability insurance nor compensate members of the public for damages.

Some U.S. utilities have failed to bring an acceptable degree of commitment to nuclear plant operation. In the aftermath of the Three Mile Island accident, the U.S. nuclear industry created its own Institute of Nuclear Power Operations (INPO), to monitor the operation of utility nuclear stations. Some of INPO's findings are very disturbing. For example, at the Peach Bottom nuclear power station in Pennsylvania, INPO reports that reactor operators were sleeping, playing video games and otherwise being inattentive while on duty in the control room. On March 31, 1987, Peach Bottom was ordered shut down by the Nuclear Regulatory Commission as a result of reports of operators sleeping on shift. In correspondence with utility management, INPO used the following language to describe its dissatisfaction with the situation:

> ...The grossly unprofessional behavior by a wide range of shift personnel, involving all shifts, and condoned by the shift superintendents reflects a major breakdown in the management of a nuclear facility. It is an embarrassment to the industry and to the nation.

Other utilities, like Duke Power headquartered in North Carolina, have brought extensive resources to the nuclear endeavour and are running successful programs.

Even so, American utilities have not generally attained the lifetime load factors that many European and Japanese utilities – and Ontario Hydro – have achieved.

The U.S. nuclear industry is at a watershed. Without rejuvenation, the industry may languish for the foreseeable future.

3. Radioactive Waste Management

The U.S. nuclear fuel cycle is presented in Figure 12. Solid arrows indicate the fuel cycle as it operates today, without commercial reprocessing and without a disposal facility in place. Broken arrows show how the cycle would be closed if the United States moved to spent fuel reprocessing and waste disposal.

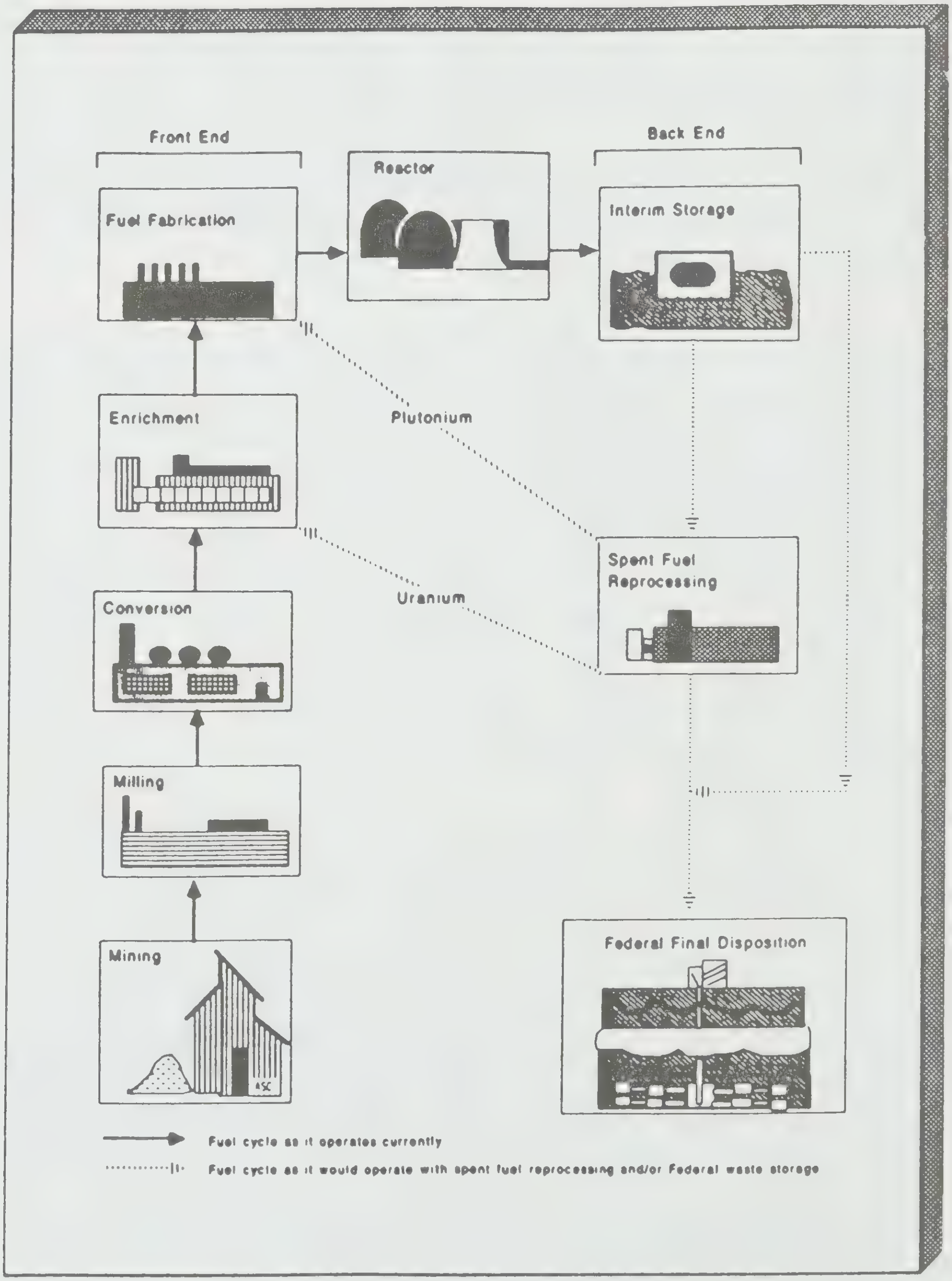
The NRC classifies radioactive materials resulting from the nuclear fuel cycle into two categories. **Effluents** are those materials discharged to the environment as gases or liquids. The active content of these effluents must fall within NRC and Environmental Protection Agency limits, and be as low as reasonably achievable. **Wastes** are those materials with sufficient radiological hazard to require special care. Wastes are in turn subdivided by the NRC into "high-level wastes" and "other than high-level wastes". High-level wastes include irradiated fuel and/or reprocessing wastes. Since no commercial reprocessing is being carried on in the United States today, almost all of the high-level waste from the nuclear power program is contained in spent fuel. Low-level wastes have commonly been buried in near-surface trenches in their shipping containers, with no intent to recover these wastes. There were formerly six commercial burial grounds in the United States but at least some of these have stopped accepting wastes. (United States, NRC, 1983)

The *Nuclear Waste Policy Act* (NWPA) of 1982 established a national policy for the disposal of high-level radioactive wastes. Under the Act, DOE is made responsible for the safe, permanent disposal of such nuclear waste materials.

> The NWPA requires DOE to site, license, construct, and operate a geologic repository; to site a second geologic repository; and to begin accepting waste for disposal by January 31, 1998. The NWPA also requires DOE to complete a detailed study of the need for and feasibility of monitored retrievable storage (MRS) and submit a proposal to Congress for the construction of one or more MRS facilities. In addition, the NWPA established a schedule and a step-by-step process for developing the disposal system. The President, Congress, affected States and Indian Tribes, DOE, and other Federal agencies are to cooperate in the development of the system. This law has provided a mandate and a process for the identification and selection of sites for repositories and the development of an overall waste management system. (United States, DOE, Office of Civilian Radioactive Waste Management,1987a, p. 6)

The Act established the Office of Civilian Radioactive Waste Management within DOE and made it responsible for implementing the Act, executing its policy and managing the national program.

Figure 12: The U.S. Nuclear Fuel Cycle



Source: United States, DOE, EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, *World Nuclear Fuel Cycle Requirements 1987*, DOE/EIA–0436(87), Washington, D.C., 27 August 1987, p. 2.

Two federal agencies are assigned the task of developing regulatory requirements for the disposal of high-level radioactive wastes. The Nuclear Regulatory Commission is the primary regulatory agency for repository siting, construction, operation and decommissioning. NRC will license the repository and define its technical criteria. The Environmental Protection Agency, EPA, is responsible for developing standards for repositories to protect the health and safety of the public.

NWPA requires that the users of nuclear-electricity pay for the cost of disposing of spent nuclear fuel. The federal government collects a fee of 1 mill per kilowatt-hour (0.1¢/kWh) from utilities operating nuclear power plants. This money accumulates in the Nuclear Waste Fund and is used to pay for all elements of the waste disposal program: the repository, any MRS facility constructed, waste transportation and federal support for state and Indian tribe participation. The status of the fund is reviewed annually to ensure that sufficient money is accumulating to cover the full cost of the disposal system. As of 31 January 1988, the fund had a balance of $US 1,967.6 million. The federal government will pay for defence wastes which are placed in the repository.

NWPA required DOE to build and operate one repository and to conduct siting activities for a second repository. Until recently, site studies for the first repository were being conducted in three different rock types; salt domes and bedded salt deposits in Deaf Smith County in Texas, basalt at the Hanford site in Washington State, and volcanic tuff (solidified volcanic ash) at Yucca Mountain in Nevada. In recent amendments made by Congress to the NWPA, the siting process was restricted to the Yucca Mountain site, over the objections of Nevada representatives, subject to site confirmation studies. The NWPA amendments direct that site-specific activities at the Hanford and Deaf Smith sites be phased out within 90 days, except for reclamation work. The requirement in the NWPA to locate a second geologic repository was repealed and replaced by the requirement that DOE report to the President and Congress between 2007 and 2010 on the need for a second repository. Authorization to site, construct and operate one monitored retrievable storage, MRS, facility was given in the amendments. At the same time, the amendments annulled the Secretary of Energy's proposal to locate an MRS on the former Clinch River reactor site at Oak Ridge, Tennessee. The amendments direct that in siting an MRS, "the Secretary shall make no presumption or preference to such sites by reason of their previous selection."

The current schedule for developing the first geological repository has the following objectives (Kay, 1988, p. 8).

• Start of exploratory shaft construction	2nd quarter 1989
• Start of *in situ* testing	4th quarter 1990
• Submission of site selection report and environmental impact statement to the President	1994
• Submission of licence application to the NRC	1995

- Receipt of construction authorization from the NRC — 1998
- Start of construction — 1998
- Start of phase 1 operations — 2003
- Start of phase 2 operations — 2006

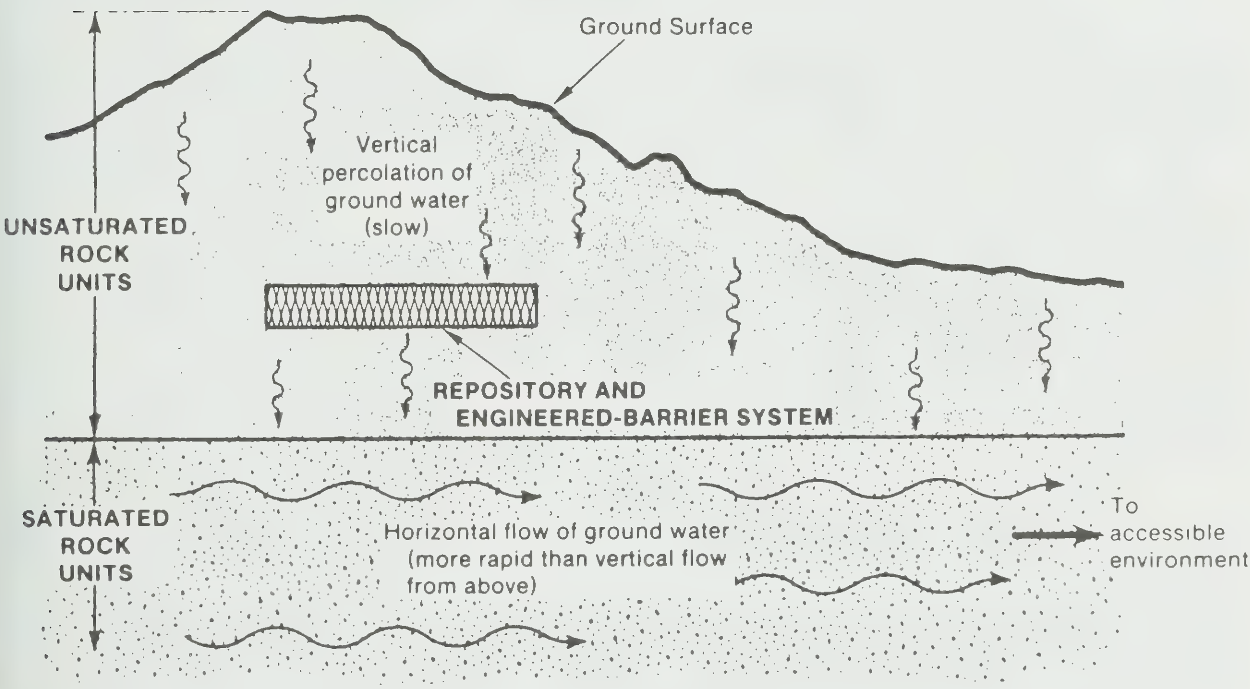
In licensing the repository, the NRC divides the approval process into four steps. These are site characterization, construction authorization, repository licensing and repository decommissioning. Reports must be submitted to the NRC and to the appropriate federal and state agencies at each stage; these documents are subject to public review. The site must meet a 10,000-year waste isolation requirement established by the EPA. Yucca Mountain is located in an arid region of the southwestern United States. The repository would be constructed above the water table in a rock zone experiencing a very slow downward flow of groundwater, as shown schematically in Figure 13.

Yucca Mountain lies in southern Nevada on the western boundary of the Nevada Test Site, about 100 miles from Las Vegas. The site straddles the junction of three blocks of federal land. Most of the repository and its associated surface facilities would lie within the Nellis Air Force Range, with smaller portions of the site lying within the Nevada Test Site and on land managed by the Bureau of Land Management.

The host rock for the repository would be a welded tuff, the solidified remains of a hot volcanic ash flow that occurred during a period of volcanism lasting from about 16 to 8 million years ago. The resulting sequence of volcanic rocks is about 6,500 feet thick at the site. The principal design criteria for a mined geologic repository are given in the following list (Personal communication: Jerome Saltzman, Office of Civilian Radioactive Waste Management, DOE, Washington, D.C., 1 May 1988).

Major Parameters	**Requirement/Criterion**
Waste types accepted	Spent fuel, vitrified reprocessing wastes and defence high-level wastes
Capacity	70,000 tonnes of waste
Receiving rate	Phase 1 (2003): 400 tonnes/year Phase 2 (2008): 3,000 tonnes/year
Isolation of radioactivity	10,000 years
Waste package containment	Substantially complete for 300-1,000 years
Groundwater travel time	1,000 years to the accessible environment
Radionuclide release rate (after 1,000 years)	1 part in 100,000 per year

Figure 13: Schematic Cross Section through the Proposed Yucca Mountain Site



Source: United States, DOE, Office of Civilian Radioactive Waste Management, *Site Characterization Plan – Overview: Yucca Mountain Site, Nevada Research and Development Area, Nevada. Consultation Draft*, DOE/RW–0161, Washington, D.C., January 1988, p. 41.

Waste emplacement at Yucca Mountain is scheduled to last for 26 years, at which time the repository is projected to be filled. Following emplacement, a "caretaker" period of 24 years begins. Over this 50-year span of time, during which various tests will be conducted to make sure the repository is functioning as expected, the waste will be retrievable. At the end of the caretaker period, the repository will be permanently sealed. The surface facilities will be decontaminated and decommissioned, and the site returned to its natural state to the extent practicable. Site markers will be erected to warn future generations of the presence of a repository. (United States, DOE, Office of Civilian Radioactive Waste Management, 1988, p. 33)

If the site characterization studies reveal that Yucca Mountain is unsuitable for locating a high-level waste repository, the exploratory facilities will be decommissioned and a new site determined.

Radioactive Waste Management in Canada

A. The Nuclear Fuel Cycle in Canada

Radioactive waste materials are created at each step in the nuclear fuel cycle, from the mining of uranium to the discharge of irradiated nuclear fuel from a reactor (followed by fue! reprocessing in some countries but not in Canada). This cycle may be subdivided into three segments for closer examination.

(1) The first stage is mining and milling of uranium ore, followed by uranium refining and fabrication into fuel elements. This sequence is often referred to as the front end of the fuel cycle.

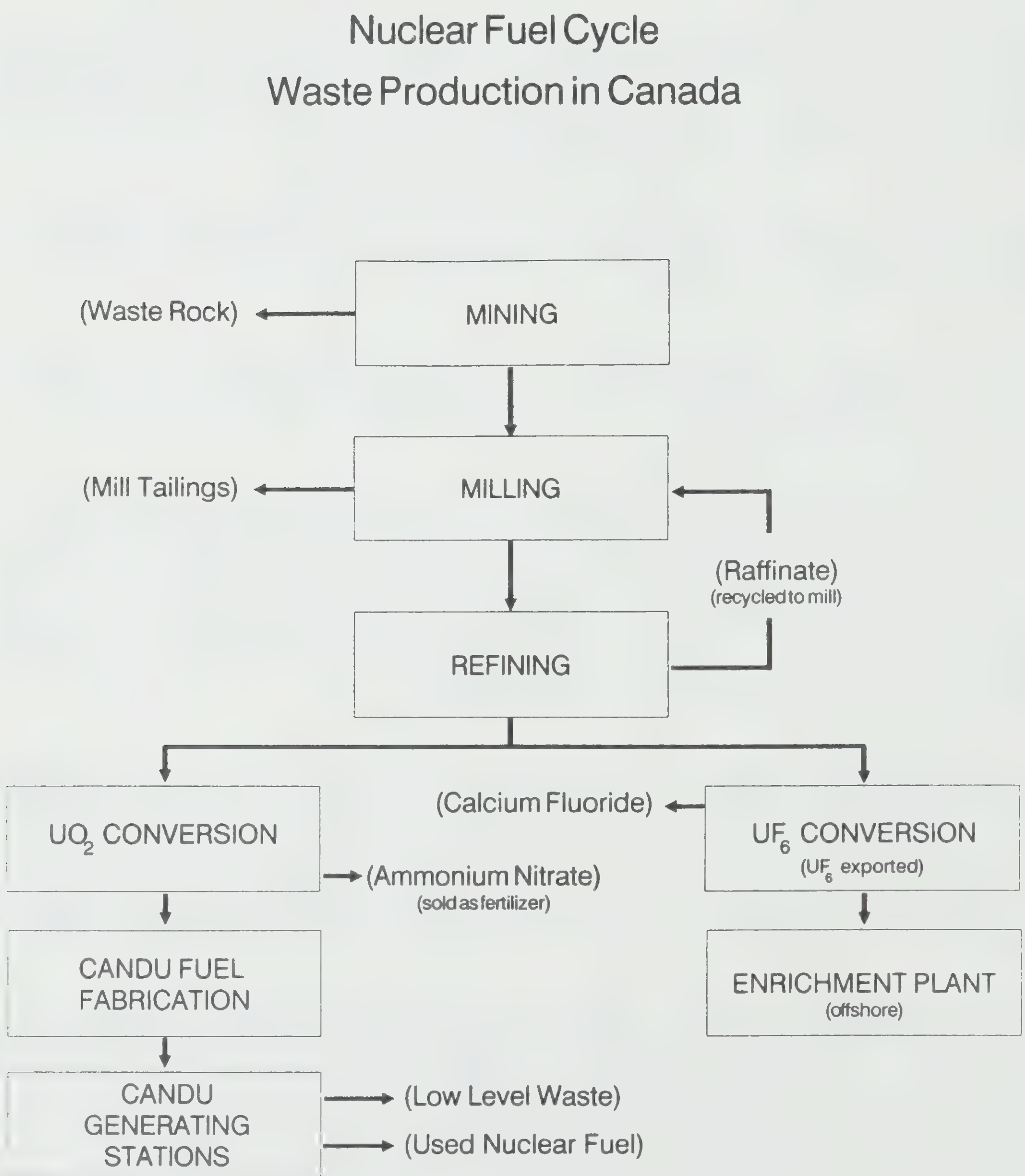
(2) The second stage is the operation of nuclear reactors for the production of electricity, accompanied by low-level releases of radioactivity in plant effluents during normal reactor operation.

(3) The third stage concerns the management of spent fuel and reactor wastes. This stage includes the interim storage and final disposal of radioactive wastes, and is often referred to as the back end of the nuclear fuel cycle. If the fuel cycle is closed and the spent fuel reprocessed, it includes the reprocessing of spent fuel and the disposal of reprocessing wastes. If the fuel cycle is open or a once-through use of the fuel, it ends with the disposal of the spent fuel.

Figure 14 displays the nuclear fuel cycle in Canada, indicating the stages at which waste materials are created. The Canadian fuel cycle has two branches. In one branch, natural uranium is fabricated into uranium oxide fuel for use in CANDU reactors. In the other branch, the uranium is converted into the gas uranium hexafluoride and exported to customers who require enriched fuel to operate light water reactors.

Uranium is one of the more common heavy elements in the Earth's crust. It is naturally radioactive; uranium and its decay products are found in rock, soil, surface and underground waters, and the oceans. Radioactive radon gas, one of the decay or "daughter" products of uranium, is a well-recognized hazard in uranium mining and has more recently been recognized as a potential hazard in some Canadian homes. Concentrations of uranium worth mining are known as "ore bodies". When uranium is mined, substantial quantities of waste rock are excavated along with the uranium ore. The waste rock contains some radioactive material but is too low in uranium content to warrant processing. Mine wastes are stored at the surface in the vicinity of the mine, and the common practice is to cover the waste rock with earth and vegetation. (Lyon and Tutiah, 1984)

Figure 14: The Nuclear Fuel Cycle in Canada and Its Associated Wastes



Source: Personal communication: Eva Rossinger, Whiteshell Nuclear Research Establishment, AECL, Pinawa, Manitoba, 4 July 1988.

The uranium ore is transported to a mill, usually located near the mine, where the uranium is separated from the remaining waste rock. The ore is crushed and ground into a fine sand to which chemicals are added to dissolve the uranium. The liquid with its dissolved uranium is then chemically treated to extract the uranium; the resulting concentrate is filtered and dried in a form known as "yellowcake". Milling wastes, or mill "tailings", include the finely ground waste rock and radioactive materials other than uranium. These wastes are discharged from the mill as a slurry and typically stored in tailings ponds. (Lyon and Tutiah, 1984) Mill tailings from some Saskatchewan mines are more radioactive, however, and are stored in concrete bunkers.

Proper management of mill tailings is important. The tailings not only contain radioactive materials arising from the uranium decay chain but also toxic elements such as arsenic and selenium which are present in the ore body. Tailings ponds should be engineered to prevent contaminated liquids from entering the groundwater system and surface waterways, and the amount of radon gas escaping to the atmosphere should be controlled. Unfortunately, uranium mine and mill tailings have not always been well managed in Canada.

Table 13 lists uranium mine/mill facilities licensed by the AECB as of 31 March 1988. All uranium mining and milling in Canada at the present time is carried out in Ontario and Saskatchewan. Table 13 does not include licences which the AECB has issued for "ore removal" or "underground exploration", where companies are extracting limited quantities of uranium ore for testing, assay or other noncommercial purposes.

Yellowcake is transported from the various mills to Canada's one uranium refinery, operated by Eldorado Resources Ltd. at Blind River, Ontario. This refinery has the capacity to produce 18,000 tonnes of uranium annually in the form of uranium trioxide (UO_3). Refinery waste is called raffinate and contains unwanted radioactive materials together with some useful uranium. The raffinate is recycled through one of two uranium mills at Elliot Lake (see Table 13) to extract more of the uranium. The remaining constituents of the raffinate are disposed of as part of the mill tailings. (Lyon and Tutiah, 1984; Canada, AECB, 1988)

The uranium trioxide produced at Blind River takes one of two conversion routes, depending on whether the uranium is destined to become CANDU fuel or whether it will be sold abroad for enrichment and use in light water reactors. Both conversion steps are carried out by Eldorado Resources at conversion plants located in Port Hope, Ontario. Most of the uranium produced in Canada is destined for export. This uranium is converted into uranium hexafluoride (UF_6) as a preparatory step to enrichment and is exported in this form. Calcium fluoride is the principal waste from this conversion process. At the present time, there is no use for the calcium fluoride and it is buried at a waste management site, but its potential as a fluxing agent in steel production is being studied. No other waste materials accrue to Canada from this branch of the nuclear fuel cycle since the enrichment plants are located in foreign countries. (Lyon and Tutiah, 1984)

Table 13: Canadian Uranium Mine/Mill Facilities Licensed by the AECB

Facility and Location	Licensee	Capacity
Cluff Lake, Phase II, Saskatchewan	Amok Ltd.	1,000 tonnes/year of uranium
Collins Bay B-Zone, Eldor Mines, Saskatchewan	Eldorado Resources Ltd.	3,200 tonnes/year of uranium
Denison Mines, Elliot Lake, Ontario	Denison Mines Ltd.	10,900 tonnes/day of mill feed 4,000 tonnes/year of acid raffinate 900 tonnes/year of limed raffinate
Key Lake, Saskatchewan	Key Lake Mining Corp.	5,700 tonnes/year of uranium
Panel Mine, Elliot Lake, Ontario	Rio Algom Ltd.	3,000 tonnes/day of mill feed
Quirke Mine, Elliot Lake, Ontario	Rio Algom Ltd.	6,350 tonnes/day of mill feed 5,000 tonnes/year of acid raffinate
Stanleigh Mine, Elliot Lake, Ontario	Rio Algom Ltd.	6,000 tonnes/day of mill feed
Stanrock Mine, Elliot Lake, Ontario	Denison Mines Ltd.	3,800 tonnes/day of ore

Source: Canada, AECB, *Annual Report 1987-88*, Ottawa, 1988, p. 18.

Uranium for use in CANDU reactors, about 20% of our uranium production, is converted into uranium dioxide (UO_2), a process which produces ammonium nitrate as waste. The ammonium nitrate has very low levels of radioactivity and is marketed as a commercial liquid fertilizer to local farmers. (Lyon and Tutiah, 1984)

Eldorado Resources also has the capability at its Port Hope operations to produce depleted uranium metal and alloys, and ammonium di-uranate.

The uranium dioxide to be used in CANDU reactors is sintered into pellets and then fabricated into fuel bundles. Negligible amounts of waste are created in the fuel fabrication step. The companies licensed by the AECB as of 31 March 1988 for fuel fabrication in Canada, the location of their facilities, and their fuel fabrication capacities are (Canada, AECB, 1988, p. 20):

- Canadian General Electric Canada Inc.:
  Toronto, Ontario– 1,050 tonnes/year of uranium as fuel pellets
  Peterborough, Ontario– 1,000 tonnes/year of uranium as fuel bundles

- Zircatec Precision Industries Inc.:
  Port Hope, Ontario– 900 tonnes/year of uranium as fuel pellets and bundles

- Earth Sciences Extraction Co.:
  Calgary, Alberta– 70 tonnes/year as uranium oxide compounds

Reactor operation results in the release of small quantities of radioactivity to the environment in liquid and airborne effluents. These releases are monitored and controlled in accordance with AECB regulations. In normal reactor operation, these releases are a very small fraction of the natural radiation to which all Canadians are exposed.

Reactor operation and maintenance also create other types of radioactive wastes. More than 99% of all the radioactivity associated with the back end of the nuclear fuel cycle is contained in the irradiated fuel discharged from Canada's power reactors. These intensely active spent fuel bundles contain an array of newly-created radionuclides. Their safe management is an essential component of the nuclear power program in Canada.

Table 14, provided by AECL's Whiteshell Nuclear Research Establishment, summarizes the generation of waste materials from the full CANDU fuel cycle. Waste quantities are those associated with the production and use of one CANDU fuel bundle, with an assumed fuel burnup of 7,500 megawatt-days per tonne of uranium. Radioactivity levels for irradiated fuel are specified one year after discharge from the reactor. At the mining and milling stages, values are given both for Ontario uranium ore and the richer Saskatchewan ore. The volume of waste generated is greatest in uranium mining and milling. Waste management practices at this stage have depended on the level of radioactivity per unit of waste volume. Mill tailings from Ontario mines are stored in the open, whereas those from some Saskatchewan operations are stored in concrete bunkers.

Low-level radioactive wastes from the nuclear power stations are placed in earth trenches, tile holes or concrete bunkers. By far the greatest amount of the radioactivity is contained in the irradiated fuel. Spent fuel is stored either in water-filled concrete-lined pools or in air-cooled, dry concrete canisters. The concrete canisters are used to store spent fuel from the decommissioning Douglas Point, Gentilly 1 and NPD reactors. Canada has not yet determined the means of finally disposing of high-level wastes but is concentrating its research program on deep burial in a stable rock formation. The philosophy here is to isolate high-level wastes until their radiological hazard has declined to an acceptable level and to manage this in such a fashion that future generations are not burdened with waste management or surveillance.

An additional aspect of the waste management issue is the decommissioning of nuclear reactors and other nuclear facilities.

Table 14: Wastes Produced in the CANDU Fuel Cycle per Fuel Bundle

Wastes from the CANDU Fuel Cycle

Amount of waste produced from one CANDU fuel bundle, which produces 33.6 million KWh of electricity, enough to supply the average Canadian home with energy for cooking, heating, etc. for more than 100 years.

		Amount		Total Activity (1)	
		Ont. ore	*Sask. ore*	*Ont. ore*	*Sask. ore*
Mining (Waste Rock)		20 Tonnes	10 Tonnes	0.0008 Curie	0.008 Curie
Milling (Mill Tailings)		20 Tonnes	1 Tonne	0.0713 Curie	0.0648 Curie
Refining (Raffinate - recycled to mill)		(8 Kilograms) (2)		0.00004 Curie	
Conversion (Ammonium Nitrate -sold as fertilizer)		(20 Kilograms) (2)		Background	
Generating Stations	Low Level Waste (3)	0.43 Cubic Metre		1.7 Curies	
	Used Fuel (4)	20 Kilograms (0.005 cu. m)		16,000 Curies	

(1) One Curie (Ci) is very nearly equal to the amount of radioactivity in one gram of Radium -226.

(2) Refinery wastes and conversion wastes are completely recycled.

(3) Average for Ontario Hydro, 1986 and 1987, as received. After processing, volume was reduced to an average of .29 cubic metres.

(4) Assuming a burnup of 7,500 MW-days per tonne. Activity specified is one year after discharge.

Source: Personal communication: Eva Rossinger, Whiteshell Nuclear Research Establishment, AECL, Pinawa, Manitoba, 4 July 1988.

B. High-Level Radioactive Waste Management

The Committee concentrated on the back end of the nuclear fuel cycle in its study of radioactive waste management. This examination extended to the countries visited by the Committee and most particularly to Sweden, where the waste management program has numerous parallels with the Canadian program.

The management of radioactive wastes at the back end of the fuel cycle is essentially a question of managing spent nuclear fuel, in the absence of reprocessing. Comparatively minor amounts of radioactivity are generated in other ways and are referred to as reactor wastes. As examples, some of the deuterium in the heavy water absorbs neutrons and is converted to radioactive tritium; water filters screen out small quantities of radioactive corrosion products; and disposable clothing may carry tiny amounts of radioactivity.

Irradiated fuel is highly radioactive and the spent fuel elements contain more than 100 radionuclides created during reactor operation. These fall within two groups. The first category includes the **fission products**, created when a heavy atom splits to form two lighter atoms. This fissioning does not always occur in the same manner and consequently an array of fission products is created within the fuel. Some of these new elements are stable; the remainder decay with their own characteristic half-lives, forming new radionuclides in some cases. The fission products are strong beta and gamma emitters and most have relatively short half-lives.

The second group of radionuclides in the spent fuel includes the **actinides**. Actinides are a series of elements with atomic number equal to or greater than 89 and similar chemical properties. Uranium and plutonium are the best known members of this group. In a CANDU reactor, one neutron per fission is absorbed by uranium–235 to perpetuate the chain reaction. The remaining 1.5 neutrons generated on average per fission are absorbed by other materials, principally uranium–238. The actinides form through a series of neutron absorption reactions and radioactive decays. They tend to be alpha emitters and many have long half-lives.

Table 15 indicates the change in composition of a CANDU fuel bundle before and after irradiation in a reactor and allowing for a cooling period of six months. Quantities are expressed in grams and the constituents total 19 kilograms. The calculation assumes a fuel burnup of 6,500 gigajoules per kilogram of uranium. Table 16 lists some of the important fission products in spent CANDU fuel. The more important actinides present in CANDU spent fuel are listed in Table 17. Both tables show activity levels at discharge, at one year, and at 10 years. Among the fission products, technetium–99, iodine–129 and cesium–135 represent the greatest long-term hazard. Among the actinides, plutonium–239 and plutonium–240 are particular long-term hazards.

Table 15: CANDU Fuel Bundle Composition Before and After Irradiation

Constituent	New Fuel (grams)	Irradiated Fuel (grams)
Actinides		
Uranium–238	18,865	18,725
Uranium–235	134	44
Other Uranium Isotopes	1	15
Plutonium	-	71
Other Actinides	-	1
Fission Products		
Iodine	-	1
Cesium	-	11
Technetium	-	4
Other Fission Products	-	128
Total Constituents	**19,000**	**19,000**

Source: Personal communication: William T. Hancox, AECL, Research Company, Ottawa, 9 February 1988.

Most of the newly-created fission products are inactive. The discharged fuel consists of 98.85% uranium oxide by weight; the remaining 1.15% – essentially made up of fission products and various plutonium isotopes – consists of 0.65% inactive fission products, 0.11% active fission products and 0.38% plutonium.

When irradiated fuel is first discharged from the reactor, the fission products dominate the radioactivity, as is apparent in comparing the activity levels in Tables 16 and 17. With time, the activity of the spent fuel declines, dropping by about a factor of 10 over the first decade as the short half-life radionuclides dwindle. At approximately 200 years, the activity of the fission products drops below the activity of the actinides, which thereafter are the principal determinant of the level of radioactivity. Fission product activity continues to fall sharply until, at 500 years, this activity has declined to roughly 1/100,000 of its initial level. Actinide activity drops slowly and, at 500 years, is down to about 1/15 of its initial level. Short-term storage under water at the reactor

sites allows the fission products to become less of a hazard, while the disposal of spent fuel is predicated on preventing the actinides from escaping from a repository.

Table 16: Selected Fission Products in Irradiated CANDU Fuel

Radionuclide	Half-Life (years)	Activity (curies/kilogram of uranium) at discharge	at 1 year	at 10 years	Significant Radiation
Tritium (H–3)	12.3	0.17	0.16	0.10	beta
Krypton–85	10.7	2.22	2.19	1.23	beta, gamma
Strontium–89	0.14	443	3.95	9.8×10^{-20}	beta, gamma
Strontium–90	29	17.5	16.0	12.9	beta
Yttrium–91	0.16	578	77	1.1×10^{-16}	beta, gamma
Zirconium–95	0.18	825	17.3	1.3×10^{-14}	beta, gamma
Niobium–95	0.10	802	36.6	2.9×10^{-14}	beta, gamma
Technetium–99	2.1×10^{5}	3.4×10^{-3}	3.4×10^{-3}	3.4×10^{-3}	beta, gamma
Ruthenium–106	1.0	182	101	0.21	beta
Iodine–129	1.6×10^{7}	7.9×10^{-6}	7.9×10^{-6}	7.9×10^{-6}	beta, gamma
Iodine–131	0.02	525	1.2×10^{-11}	0	beta, gamma
Cesium–134	2.17	16.9	11.3	0.55	beta, gamma
Cesium–135	2.3×10^{6}	4.5×10^{-5}	3.8×10^{-5}	3.8×10^{-5}	beta
Cesium–137	30.2	25.3	24.8	20.2	beta, gamma
Cerium–144	0.78	424	181	0.06	beta, gamma
Promethium–147	2.6	58.9	50.7	4.7	beta, gamma

Source: Boulton, J. (ed.), *Management of Radioactive Fuel Wastes: The Canadian Disposal Program*, AECL–6314, Whiteshell Nuclear Research Establishment, Research Company, AECL, Pinawa, Manitoba, October 1978, p. 19.

Total heat output from a bundle of irradiated CANDU fuel is displayed with time after discharge from the reactor in the upper half of Figure 15, and the activity levels of the fission products and the actinides are plotted against time after discharge in the lower half of Figure 15. These values are characteristic of CANDU fuel which has undergone an average burnup of 7,500 megawatt-days/tonne of uranium. The time scale is logarithmic and extends from one second to 10 million years. The vertical scale representing heat output in the upper illustration and radioactivity in the lower one is also logarithmic and covers 11 orders of magnitude.

Table 17: Selected Actinides in Irradiated CANDU Fuel

Radionuclide	Half-Life (years)	Activity (curies/kilogram of uranium) at discharge	at 1 year	at 10 years	Significant Radiation
Neptunium–237	2.1×10^6	2.1×10^{-5}	2.1×10^{-5}	2.2×10^{-5}	alpha, gamma
Plutonium–238	87.7	7.2×10^{-2}	8.3×10^{-3}	8.0×10^{-2}	alpha, gamma
Plutonium–239•	2.4×10^4	0.15	0.15	0.15	alpha, gamma
Plutonium–240	6.8×10^3	0.24	0.24	0.24	alpha, gamma
Plutonium–241•	14.7	22.9	21.8	14.2	beta, gamma
Americium–241	432	11.5×10^{-3}	4.7×10^{-2}	0.3	alpha, gamma
Americium–243	7.4×10^3	5.3×10^{-4}	5.3×10^{-4}	5.3×10^{-4}	alpha, gamma
Curium–242	0.45	2.58	0.44	8.9×10^{-6}	alpha, gamma
Curium–244	18.1	1.6×10^{-2}	1.5×10^{-2}	1.1×10^{-2}	alpha, gamma

• denotes a fissionable actinide.

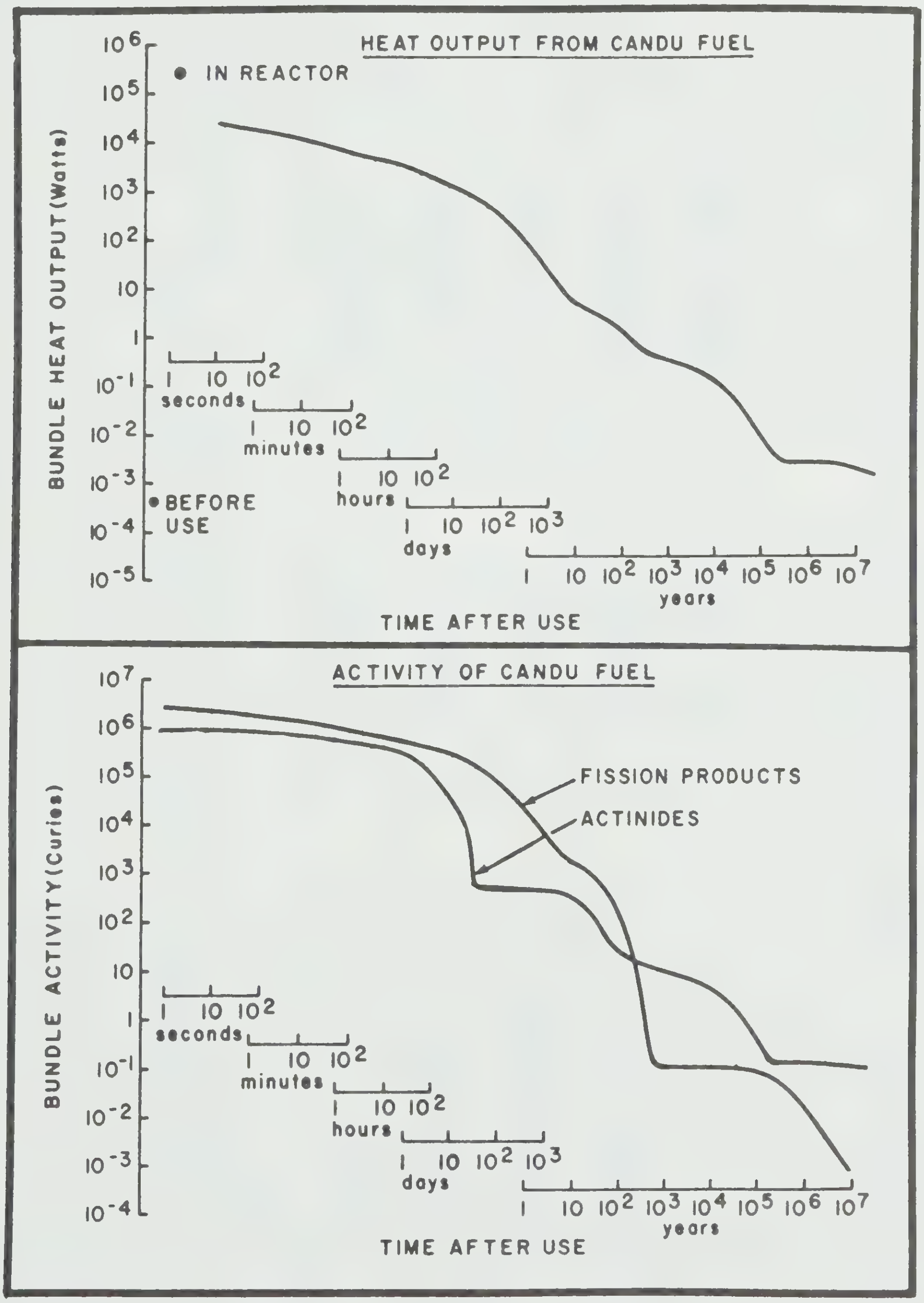
Source: Boulton, J. (ed.), *Management of Radioactive Fuel Wastes: The Canadian Disposal Program*, AECL–6314, Whiteshell Nuclear Research Establishment, Research Company, AECL, Pinawa, Manitoba, October 1978, p. 19.

Figure 15 reveals that the heat output of an irradiated CANDU fuel bundle has dropped to less than one-thousandth of its initial value within approximately three years of discharge from the reactor. Radioactivity is down to 1/10,000 of its initial value after about 100 years.

Table 18, supplied by AECL's Whiteshell Nuclear Research Establishment, provides data on the amount of irradiated fuel to be disposed of in Canada. The first column in the table gives the quantity of spent fuel generated to year-end 1987, by utility, and projects to the year 2050 what that amount will grow to, based upon the Canadian power reactors now in operation and under construction.

Although 4.35 million spent fuel bundles may seem to be a large quantity, at 20 kilograms of uranium oxide per bundle this amounts to 87,000 tonnes. For purposes of comparison, the Syncrude plant in the Alberta oil sands, operating at full production, can mine and process over 100,000 tonnes of oil sand in one 8-hour shift. [At full output, Syncrude can handle 300,000 tonnes of oil sand and produce 175,000 barrels of bitumen in a 24-hour period.] Thus the quantity of spent fuel to be managed is substantial but in no sense is it an overwhelming amount.

Figure 15: Heat Output and Radioactivity Levels of Irradiated CANDU Fuel



Source: Boulton, J. (ed.), *Management of Radioactive Fuel Wastes: The Canadian Disposal Program*, AECL–6314, Whiteshell Nuclear Research Establishment, Research Company, AECL, Pinawa, Manitoba, October 1978, p. 20.

Table 18: The Accumulation of Irradiated Nuclear Fuel in Canada

Used Nuclear Fuel in Canada

Number of Bundles

	Dec., 1987	*2050 (Proj.)*
Ontario Hydro	475,000	3,700,000
Hydro Quebec	19,700	315,000
N.B. Power	20,000	335,000
TOTAL	514,700	4,350,000

Notes:
Each fuel bundle contains 20 Kg uranium dioxide and occupies a volume of 0.005 cu. metre.
Projections are based on reactors now in operation and under construction.

Source: Personal communication: Eva Rossinger, Whiteshell Nuclear Research Establishment, AECL, Pinawa, Manitoba, 4 July 1988.

Irradiated fuel is removed from the reactor core by remotely-controlled equipment and transferred to a water-filled pool for storage. Protection against radiation is provided by about four metres of water covering the fuel stacks and the thick concrete walls of the pool. This method, commonly termed "wet storage", has been used around the world for more than four decades and provides a safe means of retrievably storing the fuel as it cools and the level of radioactivity declines. The pools are expensive to construct, however, and require considerable maintenance and monitoring. AECL has pioneered a new approach called "dry storage" in which the spent fuel is transferred to silo-shaped reinforced-concrete canisters about 6 metres tall and 2.5 metres in diameter. Rows of canisters are constructed on a concrete pad and the canister is sealed after the spent fuel has been loaded into it. Heat is carried away from the canister by natural convective air cooling. The dry storage option offers considerable savings and the canister has a design life of at least 50 years. This makes dry storage an attractive option in a delayed decommissioning strategy. The concept was tested at WNRE and has since been employed to store spent fuel at the Gentilly-1 and Douglas Point sites, and at Chalk River. Eleven canisters were needed to store the spent fuel at Gentilly-1; the larger quantity of irradiated fuel from Douglas Point required construction of 47 somewhat larger canisters.

The Canadian program for managing radioactive wastes is being carried out under a joint federal government-Ontario government agreement announced on June 5, 1978. This agreement established four main areas of responsibility in the management of such wastes. The Ontario government, through its agency Ontario Hydro, assumed responsibility for the interim storage of radioactive waste and for developing the transportation system to ship these wastes. The federal government, through its agency AECL, assumed responsibility for developing the technology for immobilizing radioactive wastes, and for ultimately developing a suitable means of permanently disposing of them.

The purpose of the disposal component of the joint program "...is to verify that permanent disposal in a deep underground repository in intrusive igneous rock is a safe, secure and desirable method of disposing of radioactive waste." The method of final disposal is being developed primarily by AECL, in consultation with other organizations. This program is subdivided into four phases: concept verification; site selection and acquisition; disposal demonstration; and full-scale operation.

Concept verification, which is currently underway, has as its objective to verify that the concept of deep geological burial will lead to a safe and environmentally acceptable solution. Under the direction of AECL, concept verification involves federal and provincial agencies, universities and private industrial organizations.

Phase two consists of site selection and acquisition. On the basis of what is learned from the concept verification phase, a variety of possible sites will be selected for further testing, in consultation with the involved communities. The mechanism by which this will be achieved has yet to be put into place, but will presumably involve a lengthy public hearings process. A single site will ultimately be selected and acquired.

Phase three is a disposal demonstration at the selected site. It is intended that the underground disposal facility would be extensively tested over a period of years, both to verify the scientific assumptions developed during concept verification and to verify the suitability of the selected site. This phase would also include the construction of a pilot plant for immobilizing the wastes before being placed in the repository.

The final phase is the full-scale or commercial operation of a disposal facility. This will only occur after the disposal technology has been established as suitable for that site. It seems likely that only one facility will be built to handle spent fuel from power reactors in Ontario, Quebec and New Brunswick.

A tentative schedule was established for the disposal component of the program. The specific targets were (Boulton, 1978, p. 59 and 61)

(a) to have verified the basic concepts of disposal of irradiated fuel or fuel wastes in deep hard rock, at least to the stage where there is general acceptance, by 1981;

(b) to have recommended technically-suitable sites for selection by governments and to have constructed a demonstration disposal repository by 1985;

(c) to have the demonstration completed to a stage where the construction of a full-scale repository could be considered by 2000.

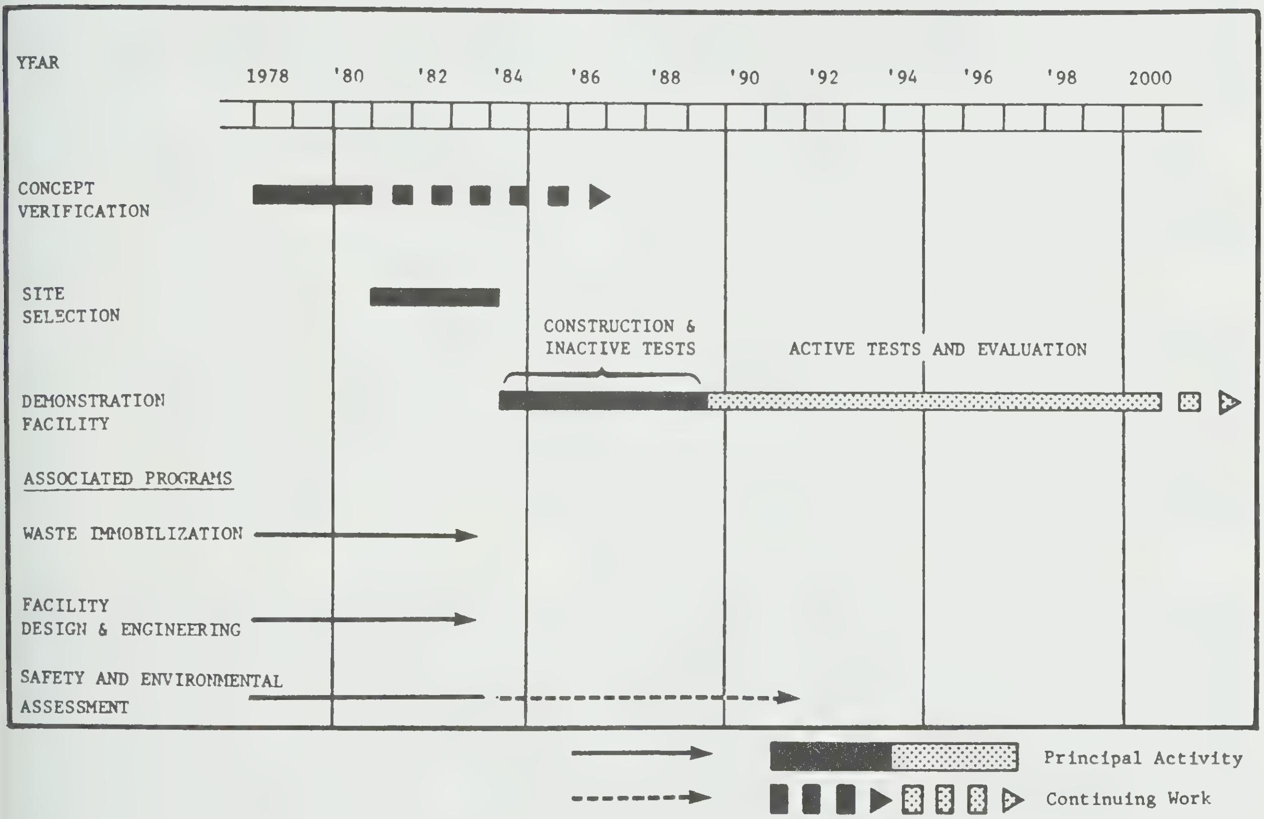
Figure 16 shows the schedule released in 1978 for the complete waste disposal demonstration program. At the time, this schedule was criticized as being unreasonably optimistic, particularly by the scientific community which understood the nature of the R&D required for the first phase, known as concept verification. Time has shown the critics to be correct.

The delays in the disposal program do not constitute a problem of public safety. Interim storage methods for spent fuel have proven to be quite satisfactory and could be used for an indefinite period of time. What does result from continuing delay is an erosion in public confidence in the waste management program, an increase in public confusion about the progress of the program, and an increase in the overall cost of R&D for the program.

By far the largest burden of R&D in support of the program falls on AECL. Unlike the past, when AECL conducted research almost entirely within its own establishment, it has reached out in this case to a wider research community. A substantial number of private companies and universities are making major technical contributions to the program.

Formerly each year, and now every six months, AECL issues a report on the progress of its waste management program; each year, an independent Technical Advisory Committee (TAC) publicly reports its views on the adequacy of the Canadian program.

Figure 16: 1978 Schedule for the Spent Fuel Disposal Program



Source: Boulton, J. (ed.), *Management of Radioactive Fuel Wastes: The Canadian Disposal Program*, AECL–6314, Whiteshell Nuclear Research Establishment, Research Company, Atomic Energy of Canada Limited, Pinawa, Manitoba, October 1978, p. 60.

The Technical Advisory Committee is comprised of ten members, selected from a list of nominees submitted by the major scientific and engineering societies in Canada. Four features of its operation guarantee its autonomy. First, TAC membership is only open to persons nominated by Canada's learned societies. Second, TAC reports annually and on a public basis. Third, TAC members are assured full and free access to all aspects of the research program. Fourth, TAC has resources made available to it for obtaining further specialist advice through consultants, as and when it judges it necessary to do so. The Committee's Swedish hosts noted that TAC had been invited to comment on Sweden's radioactive waste management program and had done so to the benefit of that program.

The Atomic Energy Control Board plays a fundamental role in the process of developing appropriate waste management technology. When the concept verification phase is pronounced complete, AECB will state its views on the acceptibility of the concept. The Board has also decided that it will apply the same licensing procedure to a disposal facility as it does to any other nuclear facility. Thus there will be a requirement for public information before site selection; the proposed site must be approved by the AECB; and Board approval will be required for construction to begin, for radioactive materials to be emplaced in the facility, for full operation, and for the eventual monitoring and surveillance of the site.

The AECB has issued a statement of regulatory policy regarding the disposal of long-term radioactive wastes (Canada, AECB, 1987a). The broad objectives of radioactive waste disposal are to (page 2):

- minimize any burden placed on future generations,
- protect the environment, and
- protect human health,

taking into account social and economic factors.

In a June 1988 statement, the federal government announced an environmental review of long-term nuclear fuel waste management in Canada. The Minister of Environment will establish a Federal Environmental Assessment Review Panel to examine the social, economic and environmental implications of long-term radioactive waste management in public hearings. Concurrently, an independent group of experts will be created to conduct a detailed scientific and technical review of the Canadian disposal concept, reporting its findings to the Panel. Assuming that guidelines are available from the Panel in 1989, AECL expects to submit its Concept Assessment Documentation to the Panel and to the Atomic Energy Control Board in 1991. Public hearings would then be convened by the Panel to review AECL's assessment. Site specific investigations would not begin until the assessment had successfully completed this government and public review process.

As its report was being completed, the Committee was advised that the Swiss Government has officially recognized the feasibility in principle of safely disposing of radioactive wastes. Sweden and Switzerland are the only two nations operating power reactors to require a formal demonstration of safe disposal, and that requirement has now been acknowledged by government to have been met in both countries. Sweden and Switzerland intend to isolate their long-lived radioactive wastes in stable, deep geological formations, as does Canada.

The Economics of Nuclear Power

As Western countries have gained experience in operating nuclear plants, there has been growing controversy about pursuing the nuclear option. While various interest groups have aired environmental and safety concerns, perhaps the most critical aspect of the nuclear debate lies in the realm of economics – for it is here that the promise of nuclear power has not entirely met with confirmation once time and operating experience provided fuller information. Competitive generating technologies have made relative gains in both performance and cost, notably in the United States.

A. The Economics of Risk

Much of the public debate on nuclear power involves engineering concerns and the probability or "risk" of a nuclear accident. This is not the definition of risk used when the financial aspect of nuclear power is discussed. Rather, economic risk primarily indicates the variability of intended returns on an investment. The question raised is: Are nuclear installations economically riskier than non-nuclear technologies for power generation?

There is growing evidence, particularly in studies conducted in the United States, that risk factors are higher for nuclear generating facilities than for non-nuclear facilities, even though utilities with nuclear plants are not necessarily a poor investment when all opportunities in the capital market are considered. If investors perceive greater risk in nuclear than in non-nuclear generating technologies, then the cost of capital – which is generally assumed to be uniform for purposes of generating cost-comparison studies – will be greater for nuclear projects, since rate of return on investment is a large component of the cost of capital.

Several major American investment houses suggest that economic risk is indeed higher with nuclear plants. Merrill Lynch, after the Three Mile Island accident, determined that institutional investors consider a utility's use of nuclear power to be a risk factor. Other brokers, such as Salomon Brothers, advise clients to be wary of companies with nuclear facilities.

Several years ago, the U.S. Federal Energy Regulatory Commission (FERC) allowed the Connecticut Yankee Atomic Energy Corporation a return on equity of 17%, which was at the time the highest rate of return ever granted to an American electric utility. In its ruling, FERC cited the risk associated with nuclear power in the aftermath of the Three Mile Island accident; investors perceive that they have little security if a utility company's sole asset is a nuclear reactor. (United States, DOE, EIA, 1984)

Three events contributing to the existence of a risk premium for nuclear power are cited in a 1984 U.S. Department of Energy study, *Investor Perceptions of Nuclear*

Power. They are: (1) the March 1979 accident at Three Mile Island; (2) the subsequent realization that the the cleanup costs of an accident of the magnitude of Three Mile Island could be over $US 1 billion, which is not fully insurable and could therefore result in substantial losses; and (3) decisions by the Tennessee Valley Authority in 1982 to cancel some of its nuclear plant construction projects and by the Nuclear Regulatory Commission to stop work on the Zimmer reactor while warning of the possible closing of the Indian Point 2 and 3 reactors. (United States, DOE, EIA, 1984)

This study suggests that as a result of the Three Mile Island accident, the value of an investment in a nuclear utility would have dropped 10% relative to an investment in a non-nuclear utility. Such a decrease could be prompted by as little as a one or two percentage point premium in the the rate of return required by investors to actually purchase such securities. Investor concern was compounded because of two additional factors. Through the end of 1982, there had been over $US 15 billion in abandonment costs resulting from the cancellation of nuclear power plants; investors were estimated to have absorbed 30% of those costs. Secondly, U.S. nuclear power plants on average have operated at only a little more than 55% of their design capacity [the average, cumulative load factor for all U.S. reactors of 150 MWe and larger was 56.6% at end-June 1987], whereas comparative cost studies had often assumed a load factor of 70%. Shareholders are also having to bear some of the costs arising from this lower-than-expected operating efficiency. (United States, DOE, EIA, 1984)

What do these U.S. findings imply for investment in Canadian nuclear facilities? The structure of the Canadian electrical power industry differs from that of the United States in several respects. The fact that most Canadian electrical utilities are publicly owned means that their shares do not trade in the stock market. Unlike American utilities, most of which are privately owned and must attract equity investment, Canadian utilities rely on provincial governments for ultimate decisions on expansion strategy, and for equity capital.

A major source of funds for Canadian utilities is indirect investment, where investors purchase long-term bonds issued by the provincial utilities. A high proportion of these bonds are floated abroad. The reliance on indirect investment accounts for the higher debt-to-equity ratios of Canadian utilities.

To the extent that provincial governments guarantee loans taken out by their utilities, Canadian utilities are in a much stonger investment position than their American counterparts. The credit rating of a Canadian public utility is directly connected to the credit rating of its parent province. Another difference is that, as a proportion of company assets, Canadian utilities do not have as high a concentration in nuclear assets as do some American utilties, although Ontario Hydro's 38% of fixed assets in nuclear generating stations is a substantial value.

Another major difference is the superior operating record of Canadian power reactors. To the end of June 1987, Canadian reactors had achieved an average, cumulative load factor of 78.7%, exceeded only by Switzerland (79.7%) and Finland

(79.3%) among those non-Communist countries operating four or more power reactors. Even considering the annual average load factor for the 12 months ending June 30, 1987 (to reflect the full impact of the shutdown of Pickering units 1 and 2 for retubing), the result was 71.4%.

Nonetheless, when cost comparisons are made between nuclear and non-nuclear technologies, the cost of capital for nuclear facilities should be risk adjusted. With the strong evidence that such risk premiums are required by private investors, utility decisions in Canada should reflect real costs in the marketplace, even though they may not show themselves as explicity as in privately owned U.S. utilities.

B. Nuclear versus Coal

The primary choice for expanding electrical generating capacity in the Western industrialized world over the next several decades is between coal-fired and nuclear plants. Regional considerations may colour the issue, but the IAEA study of new additions to electrical generating capacity referred to earlier confirms this basic choice, at least in the near-term.

Large hydro-electric stations are no longer an option in many countries because the most promising sites have already been dammed, or environmental considerations preclude development. A notable exception to this generalization is the James Bay II hydro-electric development in Quebec.

Most countries are unwilling today to accept the price risk and the security of supply risk associated with using imported oil for new base load generating capacity. Some countries with reliable access to natural gas supplies are using gas for peaking generation and even for new base load capacity. In general, however, natural gas is neither as widely available nor as inexpensive as coal for use in power generation.

This leaves coal or nuclear as the basic options open to many countries. Nuclear power is economically preferred for continuous base load electricity production, while coal firing is more readily adapted to interruptible or peaking purposes. Nonetheless, the French have demonstrated the use of power reactors in load following.

The strong embrace given nuclear power by some nations is due to a lack of alternatives, in contrast to the Canadian situation where indigenous coal is plentiful, and where technologies to transport it and burn it more cleanly are becoming viable and competitive. According to officials with whom the Committee spoke in Sweden, West Germany and France, nuclear power is clearly the cheapest large-scale generating capacity now in use and (with the exception of Sweden) is considered a necessary element of any strategy to meet electricity demand into the next century. On more emotional issues, some nuclear programs abroad have run into trouble.

In Canada, the economic question of coal versus nuclear is very much a regional consideration. Nuclear power offers a long-run cost advantage in the Ontario Hydro and New Brunswick Electric Power Commission systems, according to the best calculations of those with the actual experience of running the nuclear installations. High marks can be given to the CANDU system for performance, reliability and safety – all of which are key factors in any investment decision. In other regions, however, coal is the obvious choice, especially where generating stations can be built adjacent to or near open-pit coal mines. As coal preparation, transportation and combustion technology improves and as electricity markets continue their adjustment, indigenous coal may become a viable option for central Canada. And Canada, unlike most other industrialized nations, still has a sizeable hydro-electric potential remaining in certain regions of the country, including the north.

A commitment to nuclear power or coal-fired generation or hydro-electricity is not just a commitment to the flow of expenditures that will occur over the construction and operating life of the plant or station; it is effectively also a voluntary withdrawal from a different technology which may turn out to be preferable, as costs become known and as technology develops.

C. Indicators of Nuclear Cost in Canada

The economic track record of nuclear reactors in Canada in terms of a standardized unit energy cost has been good. AECL and Ontario Hydro have conducted studies comparing the cost experience of actual nuclear and coal installations in Ontario, showing that the nuclear plants are more economically efficient today than comparable thermal units. Through the 1990s and into the first 25 years of the next century, the gap is projected by Ontario Hydro to widen, positioning Ontario nuclear stations such as Pickering B and Bruce B at less than half of the cost per kilowatt-hour of comparable thermal stations equipped with wet scrubbers.

Even so, the economic track record for Canadian nuclear development has been less auspicious than expected. Cost overruns of huge proportions have been characteristic of nuclear installations. Pickering B, estimated to cost $1,585 million, actually cost $3,862 million (five times more than Pickering A); Bruce B, estimated to cost $3,869 million, actually cost $6,036 million and came on line two years later than originally targetted; Point Lepreau, estimated to cost $466 million, cost $1,448 million, and was four years late. Nonetheless, studies by AECL and Ontario Hydro indicate that Canadian nuclear reactors are more cost efficient than their coal-fired counterparts.

Canadian utilities generally use two approaches to express generating costs. The **annual** cost approach evaluates actual generating costs at existing or future stations, using current dollars together with assumptions on future inflation and interest rates. The result is a projection of annual generating costs varying over the life of a station. This approach is referred to as the **Total Unit Energy Cost** or **TUEC**. As applied

by Ontario Hydro, TUEC is defined as the total annual cost of producing energy (measured in current dollars) divided by the total annual energy produced (measured in megawatt-hours of electrical equivalent, including both electricity and the electrical equivalent of useful steam energy produced at Bruce A).

The **lifetime** cost approach is typically used to compare different types of future stations. The result is an average annual cost expressed in constant dollars and referred to as the **Levelized Unit Energy Cost** or **LUEC**. The LUEC for a CANDU unit in the Ontario Hydro system in 1984 was calculated to be 21 mills/kWh compared to a LUEC of 33 mills/kWh for a coal-fired plant. (This could be interpreted as an "average" score of nuclear plants compared to thermal plants in Ontario.) The average lifetime energy cost is expressed in constant dollars per megawatt-hour in some reports.

Cost estimates involving discount rates and cost of capital are subject to revision as economic conditions, and particularly interest rates, change. Labour costs escalated significantly in the late 1970s, and unforeseen delays and problems with faulty steam generators were among the unexpected events causing increased cost and delay in completing CANDU installations.

As well, the cost-comparison figures being advanced are not in fact completely comparable. Inflation is not the only reason. A power plant coming on line at a later date than scheduled is not simply costing the sum of all installation expenditures. The cost of alternate power to cover the late commissioning must also be considered, as must the significance of a service life shifted several years into the future. Construction delays generate additional carrying costs that add to the final price tag. Finally, and in the limited Canadian experience, costs are so project-specific that a generic average cost for a standardized nuclear installation does not really exist.

A characteristic of megaprojects in general, and of Canadian nuclear power plants in particular, is the impossibility of saying in advance with any confidence what these projects are likely to have cost by the time they become operational, let alone throughout their operating lifetime. If the favourable cost-efficiency reports of agencies such as AECL and Ontario Hydro are true, this must either indicate good fortune or that nuclear power is an economically superior product to the extent that billion-dollar overruns don't offset a nuclear project's economic efficiency rating compared with competing generating technologies.

The Total Unit Energy Cost (TUEC) of nuclear generation is compared to that of fossil-fuelled generation (comprising coal, oil and gas) in the Ontario Hydro system in Table 19, for the five-year period 1982-1986. The average cost calculated in Table 19 includes operations, maintenance and administration; fuel; depreciation; and financing charges. It excludes costs related to transmission, distribution and corporate administration. Also excluded on the nuclear side are costs arising from reactor decommissioning and spent fuel disposal.

Table 19: Cost Performance of Ontario Hydro Nuclear and Fossil-fuelled Stations, 1982-1986

Year	Average Cost (cents/kWh) Nuclear	Fossil	% Cost Advantage (Nuclear over Coal)
1982	1.754	3.413	49 %
1983	1.874	3.371	44 %
1984	2.197	3.445	36 %
1985	2.794	4.043	31 %
1986	3.004	4.733	37 %

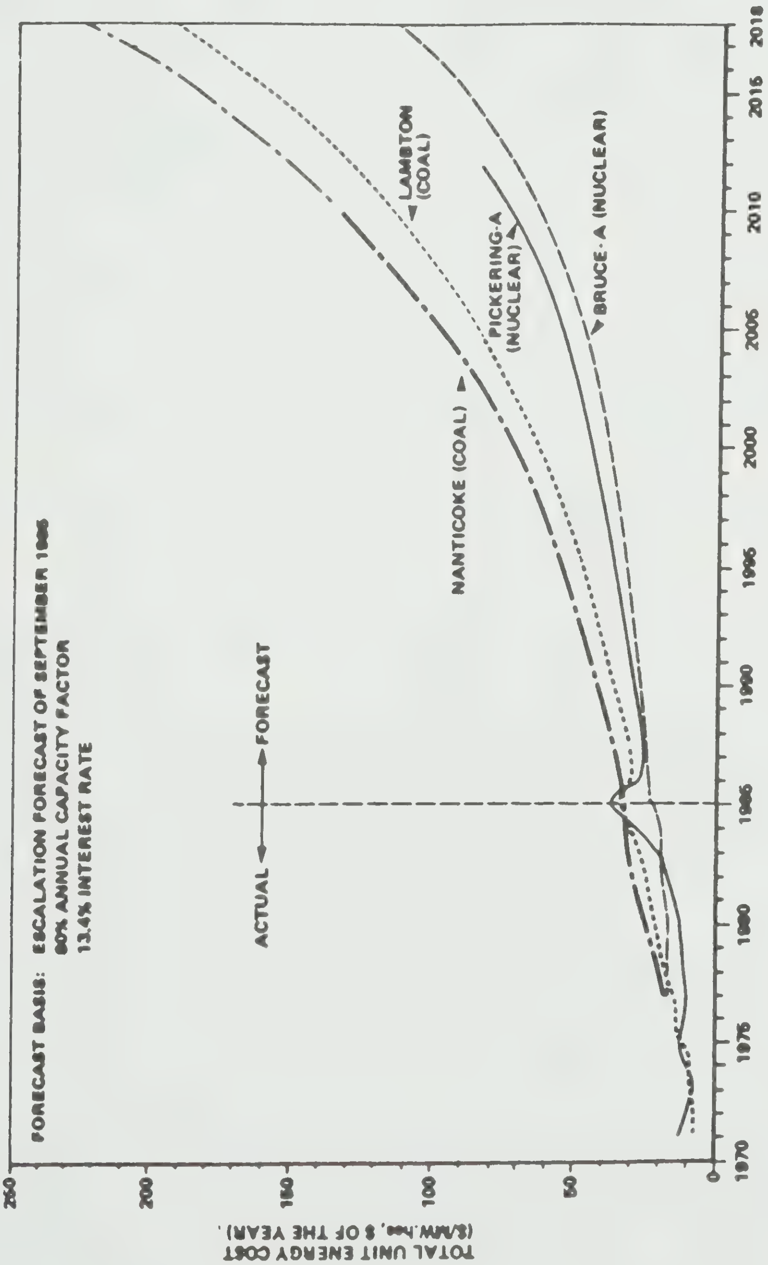
Note: Average cost per kilowatt-hour represents the costs attributable to generation but excludes costs related to transmission, distribution and corporate administrative activities. These values reflect the historical accounting costs of operating facilities and the actual energy generated by these facilities during the year. Fossil fuel costs include all use of coal, oil and natural gas.

Source: Ontario Hydro, *Inside Hydro*, Corporate Relations Branch, Toronto, December 1987, p. 109.

According to this information, nuclear generation retains a cost advantage over fossil fuel (largely coal-fired) generation. It is interesting to note, however, that nuclear's cost advantage declined over the first four of the five years covered by Table 19, recovering a little in 1986 as the remaining units under construction at Pickering B and Bruce B came into service. Over the full five-year period, the average cost of generating a kilowatt-hour of nuclear-electricity rose by 71.3% while the cost of fossil-fuelled generation rose by 38.7%. It seems reasonable then to question long-term predictions by Ontario Hydro of the growing cost advantage of nuclear over coal generation. Such a projection is displayed in Figure 17, which forecasts total unit energy costs in current dollars per megawatt-hour of electrical equivalent for the Nanticoke and Lambton coal-fired generating stations and the Pickering A and Bruce A nuclear generating stations to the year 2018.

The projections in Figure 17 "exclude the probable retrofit of SO_2 scrubbers at coal-fired stations but include provisions for pressure tube replacement at nuclear stations" (Ontario Hydro, 1986a, page 23). At the time that this forecast was made, however, Hydro had not anticipated the early retubing of Pickering NGS A units 3 and 4. The rise in the TUEC for Pickering A due to the retubing of units 1 and 2 is evident in Figure 17; it would be useful to see this projection recalculated to incorporate the early retubing of units 3 and 4.

Figure 17: Total Unit Energy Cost for Major Operating Nuclear and Thermal Stations in the Ontario Hydro System, 1970-2018



Source: Ontario Hydro, *Economics of CANDU–PHW – 1985*, NGD–10, Toronto, August 1986, page 24.

Provision for the future cost of decommissioning the nuclear stations and for the disposal of spent fuel are incorporated in the projections. Ontario Hydro introduced decommissioning and irradiated fuel transportation, storage and disposal charges into its nuclear cost accounting in 1982. Provision for future pressure tube removal costs was introduced in 1984. For the 1985 Pickering A data, the provision for future decommissioning was a unit energy cost of $0.64/MWhe and for future irradiated fuel transportation, storage and disposal was $0.73/MWhe. The unit energy cost for pressure tube replacement was $13.12/MWhe – because of this unforeseen occurrence, no provision had been made in advance for these costs which therefore had a very large effect on the TUEC. For the 1985 Bruce NGS A data, the provision for future decommisioning was a unit energy cost of $0.15/MWhe and for the future transportation, storage and disposal of spent fuel was $0.45/MWhe. The provision for future pressure tube replacement was $0.50/MWhe. (Ontario Hydro, 1986a)

From these cost projections, Ontario Hydro concluded that (Ontario Hydro, 1986a, page 23):

- the nuclear cost advantage for Pickering NGS A is expected to return once the pressure tubes are replaced;

- the base load advantage of CANDU–PHWR is expected to continue;

- the base load advantage of CANDU–PHWR is expected to increase; and

- the "inflation-resistant" characteristic of CANDU–PHWR is indicated.

Using more detailed information for 1985, the most recent year for which such data are generally available, an interesting economic comparison can be made. Table 20 summarizes the cost advantage of nuclear generation over comparable coal stations on an individual station basis. Pickering NGS A, minus units 1 and 2 out of service for retubing, is compared with the Lambton Thermal Generating Station (TGS) (4 x 495 MWe units brought into service in 1969-1970). Bruce NGS A is compared with the Nanticoke TGS (8 x 497 MWe, 1973-1978). Pickering B and Bruce B are compared with a hypothetical coal-fired station of comparable capacity and vintage, assumed to be equipped with sulphur dioxide scrubbers (neither Lambton nor Nanticoke is currently equipped with scrubbers).

If the calculation for Pickering A is made including the two shut-down reactors, then in 1985 the Lambton TGS had a 35% cost advantage over Pickering A. When Ontario Hydro plots the results (as in Figure 1 of Ontario Hydro, 1986a, p. 11, or in Figure 17 of this report), however, the Pickering TUEC is substantially lower than calculated on the basis of the 1985 data; Ontario Hydro adopted a new accounting policy in 1985 which adjusts the nuclear TUEC "to reflect application of the sinking fund for Fuel Channel Removal since the start of operation" (Ontario Hydro 1986a, p. 10 and 12). This "smoothing" of the nuclear data tends to obscure the financial impact of the retubing.

Table 20: The 1985 Cost Advantage of Nuclear Generation over Coal-fired Generation at Ontario Hydro Stations

Station	% Cost Advantage (1985) Nuclear over Coal	
Pickering A vs. Lambton (a)	17 %	(1983: 29%)
Pickering B vs. base load, coal-fired station (b)	21 %	
Bruce A vs. Nanticoke	27 %	(1983: 40%)
Bruce B vs. base load, coal-fired station (b)	21 %	

(a) Does not include Pickering units 1 and 2 which were out of service for retubing.

(b) Assumes comparable coal-fired stations are equipped with wet scrubbers.

Source: Calculated from data in: Ontario Hydro, *Economics of CANDU–PHW – 1985*, NGD–10, Toronto, August 1986.

Several comments are worth making about the information in Table 20. First, the cost advantage of Pickering A, the oldest multi-unit CANDU station, is less than that of the other nuclear stations. Since the retubing of units 1 and 2 is excluded from the comparison, this must be due to higher operating, maintenance and administrative costs for the older Pickering A station. More surprising is that the newer Pickering B and Bruce B stations have a lesser cost advantage than Bruce A, even though compared with coal-fired stations equipped with scrubbers. This reflects the relatively higher capital cost of the Pickering B and Bruce B stations, both of which have a specific cost – measured in current dollars per kilowatt of installed, net generating capacity – more than triple that of Bruce A (Ontario Hydro, 1986a, page 27).

When the data are weighted using the net station electrical outputs for 1985, the nuclear TUEC is 3.223, or about 15% higher than the 1985 value in Table 19. This would reduce the cost advantage of nuclear over coal in 1985 to about 20%. The decrease in cost advantage of nuclear generation is due to the inclusion of spent fuel management, decommissioning and other nuclear-specific costs in the detailed comparison.

The cost of nuclear regulation is not seen as a major issue in Canada. In a 1985 report (Harvie, 1985), the AECB assessed the costs of nuclear regulation, drawing principally on the findings of a contracted study by SECOR Inc. (Canada, AECB, 1981) The SECOR study identified costs associated with radiation health, safety

and environmental measures in each part of the nuclear fuel cycle. These costs were then subdivided into two components: (1) those costs which would have been incurred by a prudent operator in the absence of regulation; and (2) those costs incurred only to satisfy regulatory requirements, the so-called marginal cost of regulation.

To assess the impact of regulation on the capital cost of nuclear power generation, the Pickering B station was examined. Out of a total capital cost of the Pickering B station given as $3,097 million, $309.5 million or 10% was attributed to radiation health, safety and environmental considerations. Of this amount, $196.9 million (6.4%) was estimated to be the cost which would have been incurred by a prudent but unregulated operator; $112.6 million (3.6%) was estimated to be the marginal cost of regulation.

To assess the costs of safety and regulation in an operating reactor, the Bruce A station was selected for the 1980 operating year. The total cost of radiation health, safety and environmental measures was estimated at $30.7 million, or 8.9% of the Bruce A total cost of producing electricity that year. Of this amount, $15.55 million (4.5%) was deemed to be costs which would have been incurred by a prudent but unregulated operator; $15.15 million (4.4%) was deemed to be the marginal cost of regulation.

The AECB drew the conclusion that the cost of regulating power reactors in Canada was a relatively small proportion of the total cost of producing nuclear-electricity. The Board cautioned, however, that these findings were only approximate because they were based on the study of two specific stations and because there was uncertainty in subdividing costs to the prudent operator and to the marginal regulatory cost. In any case, "The existence of a competent regulatory authority appears to be a necessary prerequisite for public acceptance of the CANDU nuclear power program" (Harvie, 1985, p. 2).

D. The Economic Cons of Nuclear Power

1. Pattern of Expenditure

Risk and uncertainty are two undesirable, and hence expensive, components of investment projects. Safety considerations aside, nuclear power plants are perceived by many utilities to carry a greater economic risk than comparable coal-fired stations. This perception is reinforced by the testimony of the NBEPC before the Committee, regarding a second unit at Point Lepreau. Although government-owned utilities in Canada are not in the same position as are privately-owned utilities in the United States (where costs of capital are sensitive even to such factors as delay suffered due of blockages in the regulatory process arising from public pressure), carrying costs – that is, the interest rate times the capital borrowed – are just as much affected by delay.

Because the greatest share of nuclear plant costs is borne up front (given the relatively higher construction cost and lower operating and fuel costs), utilities end up with high carrying charges in any case, and the consequences of construction delay are much more costly than they might be for a thermal plant, the construction (or "capital") costs of which are a relatively lower proportion of total lifetime cost. Moreover, the time period required to bring a nuclear plant into commercial service is generally longer than for a thermal plant of equivalent capacity. This means that not only are carrying charges less with coal units, but a more flexible and responsive strategy to power planning is possible. The trend in the capital cost of Ontario Hydro's CANDU reactors, measured in current dollars per unit of installed, net generating capacity (including the electrical equivalent of useful Bruce A steam), is presented in Table 21.

Table 21: Trend in Ontario Hydro Nuclear Station Costs, Measured in Current Dollars per Kilowatt of Installed Net Electrical Equivalent Capacity

Station	Specific Cost ($ per kWe)	Year in Service
Actual Cost		
Pickering A	362.4	1971-1973
Bruce A	606.0	1977-1979
Estimated Cost		
Pickering B	1871.1	1983-1986
Bruce B	1821.8	1984-1987
Darlington	3095.3	1988-1992

Source: Ontario Hydro, *Economics of CANDU–PWH – 1985*, NGD–10, Toronto, August 1986, page 27.

It is apparent from Table 21 that the capital cost of the three more modern stations, even allowing for inflation, is significantly higher than the cost of the original Pickering A and Bruce A stations.

Among nuclear power reactors themselves, CANDU also represents a higher-cost option. The CANDU reactor system has a higher capital cost than an LWR of comparable generating capacity. To this must be added the one-time cost of the heavy water charge for the CANDU. [The estimated cost of the initial inventory of heavy water for the four new Darlington reactors is $1,539 million, almost 14% of the projected total

capital cost of the station.] Although the CANDU will cost significantly less to operate than the LWR, the up-front cost is nonetheless a very important factor in a utility's decision on the type of generating capacity that it will install.

Table 22 summarizes Ontario Hydro data comparing a four-unit CANDU station based on Bruce A costs with a comparable four-unit PWR station. All unit energy costs are expressed in 1985 dollars per megawatt-hour of electrical equivalent. Decommissioning, spent fuel disposal and retubing costs are not included in Table 22. The CANDU units are assumed to operate with an average net capacity factor of 78%; the PWR is analyzed both for a "high" capacity factor of 68% and for an "average" capacity factor of 61%.

Table 22: Ontario Hydro CANDU Costs Versus Estimated PWR Costs in 1985

		PWR	
	CANDU	**High Capacity Factor**	**Average Capacity Factor**
Station Size (MWe net)	4 x 809	4 x 809	4 x 809
Net Capacity Factor	78%	68%	61%
Interest & Depreciation Unit Energy Cost			
Dry capital	10.44	11.98	13.35
Commissioning	0.42	0.48	0.54
Fuel	0.14	0.69	0.77
Heavy water	2.75	–	–
Total Interest & Depreciation Unit Energy Cost	**13.75**	**13.15**	**14.66**
Operation, Maintenance & Administration Unit Energy Cost	4.18	4.79	5.34
Fueling Unit Energy Cost	4.65	8.90	8.90
D_2O Upkeep Unit Energy Cost	0.37	–	–
TOTAL UNIT ENERGY COST	**22.95**	**26.84**	**28.90**

Source: Ontario Hydro, *Economics of CANDU–PHW – 1985*, NGD–10, Toronto, August 1986, page 37.

The CANDU displays a lower Total Unit Energy Cost than the PWR, but some of the assumptions underlying the calculation can be questioned. The average capacity factor assumed for the PWR was 61%, based upon international operating experience through 1985. [The world capacity-weighted, average lifetime load factor for PWRs to mid-year 1987 was 62.7%.] The average cumulative load factors achieved by several industrialized countries operating (four or more) reactors has been considerably better than the "high" value of 68% assumed in Table 22. Switzerland, operating three PWRs and two BWRs, had a 79.7% cumulative load factor through June 30, 1987. Finland's record for two PWRs and two BWRs stood at 79.3%, and Belgium's eight PWRs at 78.0%. (NEI, 1988, p. 13 and 19) Thus significantly better operating records have been achieved in a few countries, for both the PWR and BWR types.

The decision to exclude pressure tube removal costs, on the grounds that "...these exclusions do not have a significant effect on the relative costs of alternative types of nuclear generation for a major program" (Ontario Hydro, 1986a, p. 36), also appears questionable. Although Ontario Hydro now includes provision for future costs of decommissioning, fuel disposal and pressure tube replacement, these provisions are said by the authors of the study to "...have too much uncertainty to be meaningful in comparisons of alternative generation types" (Ontario Hydro, 1986a, p. 36).

It is evident from Table 22 that heavy water is a significant component of cost in the Canadian program. In this calculation, the initial heavy water charge and heavy water upkeep together account for 13.6% of the CANDU TUEC of 22.95. According to Ontario Hydro, the cost of producing heavy water at Bruce is a strong function of the production rate. The 1987 heavy water cost of production is quoted by Ontario Hydro as $364 per kilogram (dividing the total 1987 heavy water production cost of $256.6 million by the output of 705 tonnes). In 1988, with a substantially lower rate of production, the unit cost is estimated to be $563 per kilogram (dividing the projected 1988 production cost of $243.1 million by the projected output of 432 tonnes). [Note that these are unit production costs, not sales values – the amount that Hydro receives for external sales of heavy water may not be directly linked to the production cost.] The utility estimates for its internal bookkeeping purposes that the cost of the initial heavy water inventory for the four new Darlington reactors will be $1,539 million, including transportation and storage charges, out of a final capital cost now projected to total $11,171 million. (Personal communication: Cameron Campbell, Government Relations, Ontario Hydro, 8 August 1988) If one assumes that an initial heavy water inventory of 0.8 tonne is required per megawatt of installed generating capacity at Darlington, then the unit cost of the heavy water is approximately $545 per kilogram (ignoring transportation and storage charges).

2. CANDU Pressure Tube Problems

The pressure tube deterioration in the Pickering A reactors is a good example of what can go wrong, even under the best conditions of planning and development. According to Ontario Hydro, the November 1987 estimate of the direct cost of materials,

labour and equipment needed to remove and replace the pressure tubes, including recommissioning, of Pickering units 1 and 2 was $402 million. Added to this is the cost of providing replacement energy: approximately $200,000-$250,000 per day for each unit. Thus the cost of replacement energy has more than doubled the direct financial impact of the retubing.

The retubing of units 1 and 2 has not only affected Ontario Hydro. Although ownership of these two units is vested in Ontario Hydro, the utility, the Province of Ontario and AECL are parties to an agreement covering their construction and operation. Under this Nuclear Payback Agreement, payments totalling about two-thirds of the financial benefit from the two reactors (based on the net operational advantage of the power generated by Pickering units 1 and 2 compared with the coal-fired Lambton units 1 and 2) have been made each year by the utility to the other two parties. Conversely, the Agreement has also committed AECL and the Province to share the costs of the retubing and the replacement energy. Since late 1983, the value of the payback has been negative and has remained so during the retubing. Ontario Hydro has not been collecting these costs from the other two parties; under an amendment to the Payback Agreement, the utility will recover this accumulated "negative payback", including interest, over the remaining life of the Agreement (to 2003). Consequently, only about one-third of the cost of the retubing will accrue to Ontario Hydro ratepayers; the remainder will in effect be deducted from revenues that AECL and the Province of Ontario would otherwise have received from the operation of units 1 and 2.

As of 31 December 1987, the negative payback amount totalled $205 million (Ontario Hydro, 1988a, p. 38), with AECL and the Province sharing this obligation about equally. Under the amended Agreement, Ontario Hydro commences recovery of this amount with the return to service of both units.

It is only fair to mention, however, that the learning experience of this problem has provided preventive measures for future installations and has engendered sophisticated and efficient technological advances in detecting and correcting pressure tube problems.

3. Nuclear Waste Management and Plant Decommissioning

The question of nuclear waste management is a contentious issue in Canada, as it is in most countries with nuclear power programs. The estimated costs of dealing with that waste remain substantially unproven, until a definitive policy on waste disposal is worked out by government and the nuclear industry. While the Committee has every confidence that nuclear waste is being dealt with conscientiously and safely in Canada, it acknowledges that this issue, and the potentially large expenditures involved in settling it, does not arise with non-nuclear power stations.

Another factor in the calculations is the cost of decommissioning nuclear

facilities. It remains unclear what the service life of a CANDU reactor may be, but a further expenditure will be incurred when the facility is taken out of service. While Canada has several facilities which are being decommissioned, the most recent being the NPD reactor, we have not yet had the experience of terminating the operational life of a large, multi-unit station. The costs of doing so in another twenty or thirty years are merely educated guesses as funds are allocated for this purpose now.

Fossil-fuelled stations, in contrast, have more potential for modernizing, as new parts and technologies can be incorporated into the station, and are also more likely to be used in a limited capacity for peaking power later in their life cycle. This allows the postponement of full-plant replacement costs, and offers the possibility of on-going refurbishment to avoid the difficulties of committing to and raising a large sum for a new plant.

A 1986 study by the Nuclear Energy Agency of the OECD, to which Canada contributed information, evaluated the cost of decommissioning nuclear facilities (OECD, NEA, 1986a). Decommissioning was divided into three stages. Stage 1 decommissioning involves blocking and sealing mechanical systems while maintaining the first contamination barrier as it was during operation. Some fuel handling systems may be kept operational for later decontamination work. Access to the containment building is controlled and the plant is kept under surveillance. Stage 2 decommissioning has the easily dismantled reactor parts removed and a long-term contamination barrier put in place. If the containment building no longer plays a role in radiological safety, it may be removed. Nonradioactive parts of the plant may be converted to new uses. Surveillance continues at a reduced level. Stage 3 decommissioning involves the removal of all contaminated equipment and structures. Unless the site is re-used, it is released without restrictions due to residual radioactivity and no further surveillance is required.

Based on these decommissioning stages and converting the national data received into 1984 U.S. dollars, the NEA calculated the decommissioning cost for a standard-sized 1,300 MWe reactor, including a contingency fund of 25%. For a 1,300 MWe PHWR of the CANDU type, the undiscounted cost of proceeding immediately to a stage 3 decommissioning was assessed at $US(1984) 145 million. If the strategy was to proceed with a stage 1 decommissioning, followed by 30 years storage and then stage 3 decommissioning, the undiscounted cost was calculated to be $US(1984) 117 million. Using a discount rate of 5% to the year of shutdown, the costs became $US(1984) 129 million for the immediate decommissioning and $US(1984) 29 million for the delayed decommissioning. (OECD, NEA, 1986a, p. 9) Assuming (1) a reactor service life of 20, 25 or 30 years; (2) either a prompt or delayed decommissioning strategy; and (3) using discount rates of 0%, 5% or 10%, the decommissioning cost for a 1,300 MWe PHWR per unit of electricity produced over the reactor lifetime was in all cases calculated to be less than one 1984 U.S. mill per kilowatt-hour. Higher discount rates and longer reactor service life lower the calculated unit cost. (OECD, NEA, 1986a, p. 62-63)

Ontario Hydro makes accounting provisions for decommissioning and fuel disposal costs within the category of "accrued fixed asset removal and irradiated fuel disposal costs" (Ontario Hydro, 1988a, p. 43). Fixed asset removal costs include the costs of decommissioning nuclear generating stations and heavy water production facilities after their service lives, and the costs of fuel channel replacements. To the end of 1987, Ontario Hydro had accrued fixed asset removal costs of $311 million ($162 million for accrued decommissioning costs and $149 million for accrued fuel channel removal costs). Hydro plans a delayed decommissioning, with a 30-year surveillance period between shutdown and dismantling. For estimating future costs of irradiated fuel disposal, Hydro assumes that a commercial disposal facility will begin receiving spent fuel in 2010. To the end of 1987, Ontario Hydro had accrued irradiated fuel disposal costs of $306 million. Hydro's annual report provides the set of assumptions used in calculating retubing, decommissioning and fuel disposal costs.

4. Government Support

Critics of nuclear development in Canada often refer to the massive amount of government funding of nuclear research and development – a subsidy unavailable to other industries in the economy. To the end of fiscal year 1978/79, a total federal investment of approximately $3.4 billion in as-spent or current dollars had been made in the development and use of nuclear power in Canada, as determined in a 1980 study prepared by the Department of Finance (Canada, EMR, 1981, p. 301-330).

This study summarized federal support in four general categories. Of the $3.4 billion invested since World War II, 56% went into nuclear power development, 22% into heavy water production, 22% into financing nuclear sales and 2% into uranium industry support.

The study also subdivided expenditures under the headings of (1) research and development – $2,137.1 million; (2) prototype reactors (Douglas Point and Gentilly 1) – $157.5 million; (3) commercial reactors – $385.5 million; (4) export reactor sales – $305.4 million; (5) heavy water plants – $540.2 million; (6) regulation and insurance – $41.8 million; (7) Eldorado Nuclear Ltd. – $64.7 million; (8) Uranium Canada Ltd. – $42.7 million; and (9) miscellaneous financial flows – $16.0 million. Some of these expenditures were in the form of loans to be repaid, for example, when an export reactor entered service or when heavy water sales were made.

The Committee has collected more recent information that suggests a further $3.3 billion has been invested by the federal government since the 1978/79 fiscal year. Most of this support – $3,085.6 million through fiscal year 1987/88 – has gone to AECL to fund nuclear R&D, the federal heavy water program, and the decommissioning and safeguarding of prototype reactors. Of this total, $816.9 million represents the forgiveness of heavy water plant loans and interest charges. From fiscal year 1979/80 through 1988/89, federal appropriations for the Atomic Energy Control Board have totalled $187.8 million. Federal funding of the nuclear fusion program, principally on

the jointly funded Varennes, Quebec Tokamak, amounts to approximately $33 million. Thus there has been a total federal investment in nuclear power approaching $7 billion over 40 years of development. Heavy water costs have been prominent in Canadian nuclear development, accounting for almost one-quarter of all federal support.

Regarding the costs of regulation, there is at present no shifting of the burden of funding the AECB – the industry regulator – onto licence holders. This is in contrast to the United States, where Congress has directed the Nuclear Regulatory Commission to collect user fees so as to offset 45% of its budget. In 1988, the NRC budget amounts to $US 392.8 million. For reference, total Canadian AECB regulatory expenditures during the period 1946-1979 were $42 million (not including AECB research expenditures of $79.2 million over that period). Annual AECB expenditures are today about $24.4 million.

Finally, there is a continuing debate between nuclear critics and the industry regarding nuclear liability insurance. At present, under the *Nuclear Liability Act*, owners of nuclear facilities must carry a total of $75 million in insurance (public liability) for each individual facility. This coverage is provided through two mechanisms.

(a) A basic level of coverage is prescribed by the AECB. Such coverage is obtained through an approved private carrier, which in Canada's case is the insurance industry pool operating the Nuclear Insurance Association of Canada (NIAC).

(b) Supplementary insurance is required to bring the total coverage to $75 million for some facilities. Such insurance may, if required, be provided through a reinsurance agreement with the federal government, subject to Treasury Board approval.

In 1987, the cost of this insurance for Ontario Hydro's Pickering A and B stations and the Bruce A and B stations was $1.667 million. For 1986, the cost of these premiums represented approximately 0.1% of the cost of nuclear generation. Insurance costs, if full liability were to be borne by the nuclear industry, would alter the economics of nuclear power. It has been argued by some nuclear opponents that the nuclear option would then become prohibitively expensive, although the U.S. NRC has advanced a proposal for full liability that it maintained could be accommodated by American nuclear utilities. The Committee does not believe that higher public liability coverage in Canada will impose an undue burden on the nuclear industry.

E. Summary Remarks

The Committee concludes on the basis of the economic data that it has reviewed that nuclear power is less expensive on a unit cost basis than fossil-fuelled generation in the Ontario Hydro and New Brunswick Electric Power Commission systems. This does not mean that nuclear costs are invariably lower. The retubing of units 1 and 2 forced the unit energy cost for the Pickering A station temporarily above

that of an equivalent Ontario Hydro coal-fired station. The impact on the unit energy cost of retubing units 3 and 4 will be less dramatic now that Hydro has established a sinking fund to cover such expenditures. NBEPC observes that the energy cost at Point Lepreau, at 5.5 cents per kilowatt-hour, exceeded the cost of oil-fired generation at Coleson Cove in 1986. However, Point Lepreau was a much cheaper source of electricity prior to the oil price collapse and nuclear-electricity will regain its cost advantage as the price of oil recovers. Adding to Point Lepreau's strength is the exceptional record that this reactor has established in its first five years of operation.

Of more concern is a general tendency for nuclear power to lose some of its economic advantage over coal with time, as indicated by the Ontario Hydro data. Even with the impact of the Pickering retubing removed, the nuclear cost advantage has been diminished. The principal culprit here is the escalation in capital cost of the Pickering B, Bruce B and Darlington stations beyond what can be readily explained by the higher inflation rates of that period. More detailed and up-to-date cost analyses are needed in these cases to track this evolution in detail and to see what it implies for the future.

On the international scene, the Committee sees a mixed picture. In France and Sweden, nuclear-electricity has a clear cost advantage over other large-scale generating alternatives, notwithstanding Sweden's decision to phase out its nuclear generating capacity. In West Germany, nuclear-electricity is less expensive than power produced from domestically mined coal and that cost advantage is expected to increase. Imported thermal coal, at its currently depressed price, can just about match German nuclear-electric costs, but West German utilities are having to install scrubbers and this major investment will force the cost of coal-fired generation to rise significantly. Both France and West Germany regard nuclear power as an essential and expanding component of their energy systems.

The U.S. nuclear program is in trouble on several fronts. Regulatory complexity and delay, litigation initiated by various groups, the proliferation of reactor configurations, and the inadequate resources and training brought by some utilities to their nuclear programs are acting to force costs up sharply. It is not clear to the Committee how these varying problems will be resolved. The U.S. Government has acted to move the radioactive waste management program ahead, which may allay some public concern, but there is little indication that government and the nuclear industry have yet discovered how to overcome the general industry malaise.

What Future for the Canadian Nuclear Industry?

As a reactor vendor, AECL's prospects in the near term are not particularly promising. Ontario Hydro will need to bring new generating capacity into its system in the 1990s but there is no guarantee that the next increment in capacity will be nuclear. Hydro-Québec is looking to an expansion of its James Bay hydro-electric complex and is unlikely to consider additional nuclear units until well into the next century. New Brunswick Electric Power Commission could be in the market for a CANDU 300, but is wary of the financial commitment. A risk-sharing agreement with the federal government seems necessary to make this project go. A CANDU 300 sale is key to AECL's international marketing strategy and the federal government should look closely at some arrangement with NBEPC.

It is clear that reactor sales alone will not carry AECL through the coming low period without financial assistance. To minimize the need the federal funding, AECL must look to other business opportunities.

One such opportunity is the Canadian Submarine Acquisition Program. In his White Paper, the Minister of Defence announced the government's intention of acquiring a fleet of 10 to 12 nuclear-powered submarines. AECL was subsequently asked to assist in the evaluation of the potential vendors of the nuclear propulsion reactor, and responded by establishing a Marine Propulsion Unit in Ottawa. A task force of senior AECL Research and CANDU Operations staff has recently been acting in an advisory capacity for the submarine program.

As the primary Canadian reservoir of knowledge and expertise in nuclear technology, one can expect that this advisory role will expand as program requirements become clearer. Because of concerns expressed by the potential foreign reactor suppliers about the confidentiality of the technology transfer, it seems likely that AECL's participation as a crown corporation would be favoured over private sector nuclear companies. It has been suggested that AECL may be named the prime contractor for all nuclear elements of the submarine program.

Given the requirements for Canadian content in the submarine program, proceeding with this acquisition would generate substantial employment in both AECL and the private sector of the nuclear industry.

Another opportunity lies in the proposed "kaon factory". The operators of TRIUMF, Canada's National Meson Facility located in Vancouver, have proposed the construction of a $400 million accelerator complex which would provide more energetic and more intense particle beams for a wide range of frontier studies in fundamental and applied science. Many of the skills required in the construction of this so-called kaon factory are common to those needed in the nuclear power industry and include robotics, remote handling, radiation monitoring and radiation shielding.

This project offers the possibility of maintaining this base of skills through expanding the operations of many participants in the industry. AECL, with its history of association with TRIUMF and its demonstrated skills in these areas of technology, seems a likely contender for significant design and engineering work.

The TRIUMF proposal is currently awaiting a funding decision by the federal government.

Within AECL itself, a number of Business Units are taking spin-off technologies from the nuclear business and attempting to establish them as commercial enterprises. The SENSYS Business Unit in Nepean, Ontario is developing an engine wear monitor for military and industrial markets. Morton-Thiokol in the United States has awarded AECL a technical studies contract for improving the engine O-ring seals on the shuttle launch vehicle, failure of which destroyed the Challenger spacecraft. A Chalk River spin-off company was established to market radiation detectors using the bubble detection method developed at AECL. These are examples of important initiatives in expanding and diversifying AECL's scope of operations.

A disturbing trend is the shortage of skilled scientific and engineering personnel which is beginning to emerge in all segments of the nuclear industry, despite the turndown in activity. Many Canadian organizations, public and private sector, are reporting difficulties in locating experienced staff to fill vacancies. Although these shortages are currently limited to intermediate and senior level positions, the reduction in undergraduates entering nuclear-related university and college programs poses a serious long-term manpower problem.

Factors contributing to the short-term shortage include normal attrition and loss of intermediate-level staff due to poor career advancement opportunities in a contracting field. The lack of interest in nuclear-related training by new students reflects the poor opinion of nuclear power held by part of the public and the apprehended lack of promotional opportunities.

Given the average age of nuclear engineering staff at the specialist level, the 30 to 40 years (and perhaps more) of operational support required for power reactors and the lack of new staff, special attention will need to be given to maintaining an adequate reservoir of technical expertise in the 1990s and beyond.

In response to the general industry downturn, certain companies have reduced or ended their nuclear-related activities. DSMA-Atcon, a private sector consulting firm formerly active in the nuclear field, apparently ceased its Canadian operations in 1986/87. The Groupe d'Analyse Nucléaire which operated at the Ecole polytechnique in Montreal no longer offers support services to Hydro-Québec. CAE's nuclear power plant simulator unit has been unsuccessful in recent contract bidding, has lost part of its nuclear staff, and its continued operation in the reactor simulator business is reportedly in question. Many of the skilled workers who have left these organizations are permanently lost to the nuclear industry. This erosion in manpower in the industrial

base supporting the nuclear power program is also disturbing.

A strong institutional framework will help sustain the nuclear industry in the years ahead. The federal government should make a clear policy statement of the part that it expects nuclear power to play in Canada's future energy development, and the degree to which it will support the nuclear option. The public needs a better explanation of the federal position on radioactive waste management, and on nuclear safety and liability. The forthcoming study by Ontario of the economics of Ontario Hydro's nuclear-electric power production will further clarify that aspect of the situation.

Appendix A

Two Dissenting Statements

Statement by the Member for Cape Breton–The Sydneys

I agree with the Committee's endorsement of nuclear power as a necessary and environmentally acceptable energy source of the future – although my reservations about its shortcomings are stronger than those portrayed in the report – and I agree with the wording of the 14 recommendations presented. My disagreement is with the Committee's acceptance of a role for private enterprise in some important aspects of nuclear development.

The Committee accepts the privatization of the Radiochemical Company and the Medical Products Division, subject to AECL being able to retain a minority interest in the new companies and to control of these entities remaining in Canada. I recommend against these elements of AECL being spun off as private companies at all, because I do not believe that it is in Canada's interest to have the marketing of a host of radioactive substances carried out as a private business, and because AECL will lose a major source of income. The manufacture and sale of radioisotopes for medical purposes, for food and wastewater irradiation, and for industrial applications will be subject to less abuse and will be better monitored if carried out as a government enterprise. I do not object in general to AECL Business Units, many of which are developing non-nuclear applications of technology, being converted into private companies.

For similar reasons I do not approve of the commercial deployment of the SLOWPOKE Energy System. Although SLOWPOKE is a comparatively safe form of thermal reactor, the prospect of having these low-power reactors dispersed across Canada in private hands for district heating purposes or as a source of process energy for industry is disturbing.

Given the innate biological hazard of radioactive materials, I prefer to see control of the applications of atomic energy kept within government.

Statement by the Member for Yorkton–Melville

New Democrats recognize and respect the public's genuine concern about Canada's active involvement in the nuclear age. As such, New Democrats were prepared to participate in this economic review of nuclear power – although it fell far short of previous Conservative promises of a Parliamentary inquiry into all aspects of the nuclear fuel cycle – in the hope that the Committee would at least approach the question of economics in an objective manner. Unfortunately, the Committee's analysis is so simplistic and so uncritically pro-nuclear that it cannot be supported by New Democrats.

The Committee fails to determine the true costs of nuclear power and fails to consider seriously the economic and energy potential of conservation and alternate energy sources such as hydrogen. The Committee's report is such a collection of selective facts, subjective assumptions and pure speculation that one is almost tempted to conclude that it was prepared by the nuclear industry itself and not by an impartial Standing Committee of the House of Commons.

Appendix B

List of Witnesses

Witness	Date	Issue
From the Department of Energy, Mines and Resources:	03/11/87	29
Arthur Kroeger, Deputy Minister		
Robert W. Morrison, Director General, Uranium and Nuclear Energy Branch		
Ted Thexton, Adviser, Nuclear		
From Atomic Energy of Canada Limited:	04/11/87	30
James Donnelly, President		
Stan Hatcher, President, Research Company		
Ronald Veilleux, Corporate Secretary and Vice-President, Corporate Relations		
Michel Therrien, Corporate Executive Vice-President		
From the National Energy Board:	18/11/87	31
Roland Priddle, Chairman		
Mark Segal, Director, Economics Branch		
Alex Karas, Director, Electric Power Branch		
From the Atomic Energy Control Board:	18/11/87	32
René J.A. Lévesque, President		
Zigmund Domaratzki, Director General, Directorate of Reactor Regulation		
David Smythe, Director General, Directorate of Fuel Cycle and Materials Regulation		
John Beare, Director, Regulatory Research Branch		
R.W. Blackburn, Director, Planning and Administration Branch		
From Energy Probe:	19/11/87	33
Norman Rubin, Director, Nuclear Research		

Witness	Date	Issue
From the Canadian Nuclear Association:	01/12/87	34
Noel O'Brien, Chairman		
Michael Harrison, President		
Ian Wilson, Vice-President		
Rita Dionne-Marsolais, Vice-President, Information		
Nick Ediger, Director and Past Chairman		
From the Canadian Electrical Association:	15/12/87	37
Wallace Read, President		
Hans Konow, Director, Public Affairs		
From Ontario Hydro:	16/12/87	38
Lorne McConnell, Vice-President, Power System Program		
Mitch Rothman, Chief Economist and Director, Economics and Forecast Division		
Ken Snelson, Manager, Bulk Electricity System Resources Planning Department		
Ted Bazeley, Manager, Nuclear Fuel Supply Department		
Richard Furness, Government Relations Officer		
From Passmore Associates International:	02/03/88	39
Jeff Passmore, President		
David Argue, Senior Associate		
From the New Brunswick Electric Power Commission:	04/03/88	40
Terry Thompson, Director, Public Affairs		
A.R. Mackenzie, Plant Manager		
From Marbek Resource Consulting:	10/03/88	41
Brian Kelly, President		
From Torrie, Smith and Associates:		
Ralph Torrie, President		

Witness	Date	Issue
From TransAlta Utilities Limited:	10/05/88	42
Walter Saponja, Senior Vice-President, Generation		
Edward J. Barry, Vice-President, Research		
From the Ontario Nuclear Safety Review:	14/06/88	43
F. Kenneth Hare, Commissioner		

Appendix C

Committee Travel

The Standing Committee on Energy, Mines and Resources made three trips within Ontario and two trips internationally to broaden its knowledge and understanding of nuclear power development in Canada and in selected foreign countries. The organizations and individuals with whom the Committee consulted during this travel are listed below.

Committee Travel to Chalk River Nuclear Laboratories, March 1,1988

Chalk River Nuclear Laboratories, Chalk River

Peter J. Harvey, General Manager, Chalk River Nuclear Laboratories

Ralph E. Green, Vice-President, Reactor Development

Howard K. Rae, Vice-President, Radiation Applications and Isotopes

J.C. Douglas Milton, Vice-President, Physics and Health Sciences

Donald H. Charlesworth, Director, Waste Management Technology Division

Bernard DeAbreu, Manager, Reactor Operations Branch

Rudy M. Lepp, Manager, Components and Instrumentation Division

Gerald F. Lynch, General Manager, Local Energy Systems Business Unit

Norman E. Gentner, Radiation Biology Branch

William R. Taylor, Technical Specialist, Mechanical Systems Design Branch

Lorna E. Evans, Manager, Public Affairs

Committee Travel in Southern and Eastern Ontario, March 20-23,1988

Canadian General Electric, Peterborough

Paul Schofield, Vice-President, Power Systems and Services

Sil Dragan, Manager – Marketing, Nuclear Fuel Handling Operations, Power Systems and Services

Dean A. Wasson, Manager – Nuclear Products, Power Systems and Services

Dave Irwin, Manager – Nuclear Fuel Handling Operations, Power Systems and Services

Harvey R. Lee, Manager – Nuclear Fuel Operations, Power Systems and Services

Invar Manufacturing Ltd., Batawa

Brian Riden, Vice-President and General Manager

Maurice Mainville, General Sales Manager

James A. Steenburg, Material Control Manager

CANDU Operations, Atomic Energy of Canada Limited, Mississauga

Don S. Lawson, President

H.M. VanAlstyne, Vice-President, Technical

Dennis R. Shiflett, Vice-President, Engineering Services Business Unit

L. John Ingolsfrud, Vice-President, Ontario Hydro Business Unit

David N. Harrington, Executive Assistant to the President

Masoneilan/Dresser Canada, Inc., Mississauga

Brian E. Minns, Vice-President and General Manager

Ray Briggs, Sales and Marketing Manager

Babcock & Wilcox Canada, Cambridge

Paul Koenderman, President

James Smith, Manager, Nuclear Products Marketing

Malcolm Cox, Manager, Projects

Dennis Dueck, Manager, Facilities Engineering

Bruce Nuclear Power Development, Ontario Hydro, Tiverton

Terry D. Squire, Corporate Relations

Brian Wood, Operation Manager

Darrell Davidson, Manager

Les Broad, Station Manager, Douglas Point Generating Station

Cameron D. Campbell, Analyst, Government Relations, Corporate Relations Branch (Toronto)

RESOLUTE Development Corp., Kincardine

Sam MacGregor, President

Committee Travel in Sweden, West Germany and France, April 8-16,1988

Sweden

Canadian Embassy, Stockholm

His Excellency Dennis B. Browne

Gregory J. Kozicz, Third Secretary and Vice-Consul

Miljö- och Energidepartementet / Ministry of Environment and Energy, Stockholm

Rolf Annerberg, Under-Secretary of State

Lars Ekecrantz, Expert

Kärnkraftsäkerhet och Utbildning AB / Nuclear Training and Safety Centre, Nyköping

Rolf I. Odin, Senior Engineer and Project Manager

Statens strålskyddsinstitut / National Institute of Radiation Protection, Stockholm

Gunnar Johansson, Radiation Protection Officer

Statens kärnbränslenämnd / National Board for Spent Nuclear Fuel, Stockholm

Olof Söderberg, Director

Nils Rydell, Chief Engineer

Margaretha Stålfors, Director of Finance

Statens kärnkraftinspektion / Swedish Nuclear Power Inspectorate, Stockholm

Sören Norrby, Director, Division of Nuclear Waste

Studsvik Energiteknik AB, Nyköping

Walter Hübner, Vice President, Research and Development, Energy Technology Division

Claes Harfors, Vice President, Power Plant Services, Nuclear Division

Eric Hellstrand, Vice President, Safety and System Analysis, Nuclear Division

Lennart Devell, Deputy Head, Safety and System Analysis, Nuclear Division

Per Linder, Project Manager, Nuclear Division

Svensk Kärnbränslehantering AB / Swedish Nuclear Fuel and Waste Management Company, Stockholm

Sten Bjurström, President

Vattenfall / Swedish State Power Board, Östhammar

Arthur Monsen, Service Department Manager

Federal Republic of Germany

Canadian Embassy, Bonn

His Excellency W.T. Delworth

Maureen Lofthouse, Counsellor, Science and Technology

Richard Têtu, Counsellor, Political

Christian Luckner, Science and Technology

Dennis Baker, Canadian Consul General (Düsseldorf)

Government of the Federal Republic of Germany, Bonn

Albert Probst, Parliamentary Secretary of State, Federal Ministry for Research and Technology

Martin Grüener, Parliamentary Secretary of State, Federal Ministry for Environment, Nature Conservation and Reactor Safety

Rheinisch–Westfälisches Elektrizitätswerk AG, Essen

Klaus P. Messer, Director

France

Canadian Embassy, Paris

Alain Dudoit, Political Counsellor

Robert Hage, Counsellor, Political Affairs

Jean-Pierre Juneau, Minister-Counsellor, Political Affairs

Ian MacLean, Economic Counsellor

Commissariat à l'Énergie Atomique / Atomic Energy Commission, Paris

Pierre Cachera, Director, Technology and Equipment

Philippe Hammer, Assistant to the Technology Director

Philippe Raimbault, Liaison – International Relations

Framatome, Paris

Pierre-Yves Gatineau, President, International Relations

Association France–Canada , Paris

Senator Adolphe Chauvin, President

Agence Nationale pour la gestion des Déchets Radioactifs / National Agency for Nuclear Waste Management, Paris

Armand Faussat, Assistant Director

Institut National des Sciences et Techniques Nucléaires / National Institute of Nuclear Science and Technology, Saclay

Yves Chelet, Director

Georges Le Guelte, Assistant Director

Committee Travel to Washington, D.C., May 1-4,1988

Canadian Embassy

Leonard H. Legault, Deputy Head of Mission and Minister (Economic)

T. D'Arcy McGee, Counsellor (Energy)

Henry C. Armstrong, Counsellor (Commercial)

Jonathan Fried, First Secretary

Ross Glasgow, First Secretary

Department of Energy

Theodore J. Garrish, Assistant Secretary

Del Bunch, Principal Deputy Assistant Secretary for Nuclear Energy

Richard H. Williamson, Deputy Assistant Secretary for International Affairs

Jerome Saltzman, Deputy Director, Office of Facilities Siting and Development, Office of Civilian Radioactive Waste Management

Mary Ann Novak, Special Assistant to the Assistant Secretary for Nuclear Energy

Betsy O'Brien, Data Analysis and Forecasting Branch, Energy Information Administration

Dan Nikodem, Office of Nuclear and Alternate Fuels, Energy Information Administration

Wanda M. Klimkiewicz, International Program Assistant, Office of International affairs and Energy Emergencies

Senate Committee on Energy and Natural Resources

Benjamin S. Cooper, Professional Staff

Mary Louise Wagner, Professional Staff

Marilyn Meigs, Professional Staff Member, Office of Senator James A. McClure

Nuclear Regulatory Commission

Harold Denton, Director, Government and Public Affairs

Stuart A. Treby, Assistant General Counsel for Rule Making and Fuel Cycle

Joseph F. Sento, Acting Assistant General Counsel for Hearings

Hans B. Schechter, Senior International Relations Specialist, Office of International Programs

Congressional Research Service

Warren H. Donnelly, Senior Specialist

Robert L. Civiak, Head, Advanced Technology Section, Science Policy Research Division

Carl E. Behrens, Head, Fuels and Mineral Section, Energy and Natural Resources Division

Francis T. Miko, Specialist in International Relations, Foreign Affairs & National Defense Division

Mark Holt, Energy Policy Analyst

U.S. Council for Energy Awareness

Harold B. Finger, President and Chief Executive Officer

Bill Harris, Senior Vice President

Paul Turner, Vice President, Industry Communications and Publications

John R. Siegel, Vice President, Technical Programs

Carl A. Goldstein, Vice President, Media and Public Relations

U.S. Public Interest Research Group

Kathleen Welch, Energy Policy Coordinator

Ken Bossong, Critical Mass Energy Project

House of Representatives Subcommittee on Energy and Power

Sue Sheridan, Counsel

Tom S. Runge, Counsel

Pat Davis, Counsel, Nuclear Regulatory Commission

American Nuclear Energy Council

Edward M. Davis, President

John T. Conway, Chairman and Executive Vice President, Corporate Affairs, Consolidated Edison Company of New York, Inc.

Andrea Dravo, Vice President, Strategic Planning

Kevin Billings, Vice President, Government Affairs

Diane Holmes, Director, Development

Duke Power Company

K.P. Lau, Congressional Affairs Specialist, Design Engineering Department

Committee Travel in Ottawa Area, May 26, 1988

AECL Radiochemical Company, Kanata

Paul O'Neill, President

David Drummond, Manager, Isotope Quality Control

John Worswick, Manager, Cobalt Operations

Jeff Norton, Manager, Cobalt Operations

AECL Medical Products Division, Kanata

Frank H. Warland, Vice-President

Peter E. Habgood, General Manager, Manufacturing

Robert L. Wolff, General Manager, Service, Technology, Human Resources and Administration

Steve R. Lee, Director, Sales

SENSYS, Nepean

Philip Campbell, General Manager

Appendix D

Abbreviations and Acronyms Used in the Report

AEC	Atomic Energy Commission (United States and Japan)
AECB	Atomic Energy Control Board
AECL	Atomic Energy of Canada Limited
AGR	advanced gas-cooled reactor
ANDRA	Agence Nationale pour la gestion des Déchets Radioactifs (National Radioactive Waste Management Agency, France)
ANEC	American Nuclear Energy Council
Bq	becquerel (unit for measuring radioactivity)
BWR	boiling water reactor
CANDU	CANada–Deuterium–Uranium
CANDU–BLW	CANDU boiling light water reactor
CANDU–OCR	CANDU organically-cooled reactor
CANDU–PHWR	CANDU pressurized heavy water reactor
CEA	Canadian Electrical Association
CEA	Commissariat à l'Énergie Atomique (France)
CERN	European Organization for Nuclear Research
CGE	Canadian General Electric Company
CLAB	central interim storage facility for spent nuclear fuel (Sweden)
CNA	Canadian Nuclear Association
CRNL	Chalk River Nuclear Laboratories
DOE	Department of Energy (United States)
ECCS	emergency core cooling system
EdF	Électricité de France (France)
EIA	Energy Information Administration (United States)
EMR	Energy, Mines and Resources, Department of
EPA	Environmental Protection Agency (United States)
EURATOM	European Atomic Energy Community
FBR	fast breeder reactor
FRG	Federal Republic of Germany
GCR	gas-cooled reactor
GGCR	graphite-moderated gas-cooled reactor (French GCR)
HTR	high-temperature reactor
HWP	heavy water plant
HWR	heavy water reactor
IAEA	International Atomic Energy Agency (Austria)
INPO	Institute of Nuclear Power Operations (United States)
KSU	Kärnkraftsäkerhet och Utbildning AB (Swedish Nuclear Training and Safety Centre)

KWU	Kraftwerk Union (West Germany)
LMFBR	liquid-metal-cooled fast breeder reactor
LWGR	light water graphite-moderated reactor
LWR	light water reactor
MWe or MW	megawatts (electrical)
MWt	megawatts (thermal)
NBEPC	New Brunswick Electric Power Commission
NEA	Nuclear Energy Agency (of the OECD, France)
NEB	National Energy Board
NEI	Nuclear Engineering International (United Kingdom)
NGS	Nuclear Generating Station
NIAC	Nuclear Insurance Association of Canada
NPD	Nuclear Power Demonstration
NRC	Nuclear Regulatory Commission (United States)
NRU	National Research Universal
NRX	Nuclear Research Experimental
NWPA	Nuclear Waste Policy Act (United States)
O&M	operating and maintenance
OECD	Organisation for Economic Co-operation and Development
PHWR	pressurized heavy water reactor
PTB	Physikalisch-Technische Bundensanstalt (Physical-Technical Agency, West Germany)
PWR	pressurized (light) water reactor
R&D	research and development
RBMK	Reactor Bolche Molchnastie Kipiache (Soviet LWGR of Chernobyl type)
R,D&D	research, development and demonstration
RCC	Radiochemical Company
RWE	Rheinisch–Westfälisches Elektrizitätswerk (West Germany)
SFR	final repository for reactor waste (Sweden)
SKB	Svensk Kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Company)
SKI	Statens kärnkraftinspektion (Swedish Nuclear Power Inspectorate)
SKN	Statens kärnbränslenämnd (Swedish National Board for Spent Nuclear Fuel)
Skr	the Swedish unit of currency, the krona
SSI	Statens strålskyddsintitut (Swedish National Institute of Radiation Protection)
THTR	thorium high-temperature reactor
USCEA	U.S. Council on Energy Awareness
WNRE	Whiteshell Nuclear Research Establishment
ZEEP	Zero Energy Experimental Pile

Appendix E

Terminology

The definitions in this and the following section on terminology are taken, with minor modifications, from the NEB report *Electric Power: A Compendium of Terms*, Information Bulletin 8, May 1985; from the Ontario Hydro report *Meeting Future Energy Needs: Draft Demand/Supply Planning Strategy*, Report 666 SP, December 1987; and from the World Energy Conference report *Energy Terminology*, 2nd Edition, Pergamon Press, 1986.

Terminology: Electric Power Systems

Acid rain: A general term describing precipitation in any form that has been acidified by the presence of atmospheric pollutants, primarily the oxides of sulphur and nitrogen.

Alternating current: An electric current that flows alternately in one direction and then in the reverse direction. In North America, the standard for alternating current is 60 complete cycles per second; such electricity is said to have a frequency of 60 hertz. Alternating current is used in almost all aspects of power systems because it can be transmitted and distributed much more economically than direct current.

Alternative energy/technology: Energy sources or technologies which are not yet widely used, as opposed to "conventional" energy/technology. The term usually refers to renewable energy sources and small, decentralized installations. Examples are photovoltaics, solar heating, wind power and waste-fueled electrical generation.

Assured system capacity: The dependable power-generating capacity of system facilities available for serving system load after making provision for required reserve generation, including the effects of agreements with other systems.

Asynchronous tie: A direct-current interconnection between two alternating-current systems, so-called because the two systems need not be in synchronism with each other.

Average energy: The energy which would be generated by the hydro-electric stations in a river system under average streamflow conditions.

Average streamflow: The arithmetic average of all recorded flows in a river over a specified period of time, usually measured on an annual basis.

Avoided cost: The cost which would be incurred by an electric utility in providing new generating capacity if the utility were to provide the power itself instead of purchasing it from an independent generator.

Base load: The minimum continuous load over a given period of time.

Base-load generating station: A generating station which is normally operated to supply all or part of the base load of a system and which consequently operates at full output whenever available. Base-load generating units tend to be large units with low operating costs.

Bulk electricity system: The generation and high voltage transmission facilities (generally 115 kilovolts and up) considered as a whole.

Bus: A set of electrical conductors that serves as a common connection for two or more circuits. A bus may be in the form of rigid bars ("busbars") or in the form of cables.

Capability: The maximum load that a station or equipment is capable of carrying under specified conditions.

Capacity: The rate of delivery of energy (for example, a utility might sell 50 megawatts of capacity or electric power); or

The maximum quantity of power that a piece of equipment or a system is capable of carrying or supplying (for example, a generating unit might have a rated capacity of 50 megawatts).

Capacity factor: For any equipment, the ratio of the average load during some period of time to the rated capacity of the equipment. Capacity is usually expressed as a percentage.

Circuit: Any conductor or set of conductors intended to carry electricity.

Circuit breaker: A switching device to open or close an electric power circuit during either normal system operation or fault conditions.

Cogeneration: The combined production of electricity and useful heat (usually steam).

Control centre: The control room from which instructions are issued for switching of power system equipment, stations or lines, and for changing the amount of power generated in power stations. Typically such a centre is equipped with remote controls, telemetering and computer facilities. Automated system maps indicate the operating status of generating units, transmission lines and main substation equipment. Metering devices show the loads being carried by units and lines, and the voltage levels at selected locations. Thus the system supervisor is provided with a complete picture of the main features of the power system and can coordinate its operations.

Converter station: An installation for converting direct current into alternating current, or for changing one frequency of alternating current to another.

Current: The flow of electricity in a conductor. Current is measured in amperes.

Demand: The desire of purchasers for electricity. "Demand" is often used synonymously with "power" which is the rate at which electrical energy is being delivered.

Demand charge: The component of a two-part price for electricity which is based on a customer's highest power demand reached in a specified period, usually a month, regardless of the quantity of energy used. The other component of the two-part price is the energy charge.

Demand management: Actions taken by a utility or other agency intended to influence the amount or timing of customers' use of electricity. These actions can be divided into three groups: load growth, load shifting and load reduction.

Dependable capacity: The load-carrying ability of a station or system under adverse conditions, as for example, the capacity of a hydro-electric station under defined low-flow conditions.

Direct current: Current that flows continuously in one direction (as opposed to an alternating current). The current supplied from a battery is direct current.

Direct current transmission: Transmission of electricity by direct current instead of the usual alternating current. Direct current has certain advantages for long-distance point-to-point transmission and for interconnecting power systems that would otherwise be unstable if an attempt were made to tie them together by alternating current transmission. There are four high-voltage dc installations in service in Canada: (1) the Vancouver Island underwater transmission link; (2) the Nelson River (Manitoba) overhead transmission line; (3) the Eel River (New Brunswick) asynchronous tie; and (4) the Chateauguay (Quebec) asynchronous tie.

Distribution system: The lines, transformers, switches, etc. used to distribute electricity over short distances from the transmission system to customers. Distribution generally takes place at relatively low voltages (44 kilovolts and less).

Economy energy: Energy sold by one power system to another to effect a saving in the cost of generation when the receiving utility has adequate capability to supply the loads on its own system.

Electrical utility: An organization that has as its prime purpose the generation, transmission and/or distribution of electric energy for sale.

Electro-technology: A technology that uses electricity in its processes, especially new technologies used to displace other energy sources. An example is the use of electrically-driven heat pumps for kiln drying wood, in place of air heated by on-site fuel combustion.

Energy charge: The component of a two-part price for electricity that is based on the amount of energy taken. The other component of price is the demand charge.

Extra high voltage (EHV): Any transmission voltage higher than those commonly used. The utility industry has generally considered EHV to be 345 kilovolts (kV) or higher, although such voltages are becoming increasingly common.

Firm power: Electric power intended to be available at all times during the period of the agreement for its sale.

Forced outage rate: The probability that a particular generating unit or other system component will be unavailable for service because of breakdown.

Fuel replacement energy: Energy sold by one utility to another to enable the purchaser to avoid burning fuel in its own thermal generating facilities. Fuel replacement energy is typically priced at a percentage of the fuel cost avoided by the purchasing utility.

Generating station: A station comprising one or more generating units for the production of electricity. The main types of generating stations are hydro-electric, nuclear-electric and fossil-fueled (by coal, oil or natural gas). In some parts of the world, such as The Geysers region of California, geothermal-electric power is becoming an important element in generating capacity.

Generating unit: An electric generator, the prime mover that drives the generator, and all the associated equipment that must be operated together as a group to generate electricity. A generating unit can usually operate independently of other units at a multi-unit station.

Generation rejection: Disconnecting selected generating units from a power system to preserve the continuing safe operation of the rest of the system. This action is sometimes taken if a large block of load has suddenly been cut off by some emergency, leaving generators feeding into the system without enough connected load to absorb their output. The units would otherwise overspeed, raising the frequency and voltage on the system to unacceptable levels.

Grid: A network of electric power lines and connections.

Head (hydraulic): The difference in elevation between the water level immediately above a hydro-electric generating station and the water level immediately below it. The power output of the station is proportional to the hydraulic head.

Heat rate: A measure of generating station thermal efficiency, generally expressed as British thermal units per net kilowatt-hour. It is computed by dividing the total heat (Btu) content of the fuel burned by the resulting net kilowatt-hours of electricity generated. In metric units, the heat rate is expressed as kilojoules per kilowatt-hour.

Hertz: The unit of frequency for alternating current, formerly given in cycles per second. The standard frequency for power supply in North America is 60 hertz.

High tension: Any voltage in excess of 750 volts.

Hydro-electric station: An electric generating station in which the prime movers are hydraulic turbines.

Incremental generating cost: The cost of generating one additional unit of electric energy above some previously determined base quantity.

Independent (private) generation: Generation owned or operated by producers other than a utility. These producers usually have generating plants for the purpose of supplying electric power required in their own industrial and commercial operations. The term also covers private plants whose sole purpose is the sale of electricity to a utility.

Installed (generating) capacity: The capacity measured at the output terminals of all the generating units in a station, before deduction of station service requirements.

Integrated planning: Joint planning by different power systems in order to minimize total costs. Integrated planning is one characteristic of a true power pool.

Interconnection agreement: An agreement made between two power utilities to govern the operation of interconnections between their systems. Typically such an agreement defines different classes of inter-utility electricity transfers and specifies how they shall be priced between the two companies.

Interconnected system: A system consisting of two or more individual power systems connected together by tie lines.

Interruptible energy: Energy made available under an agreement that permits curtailment or interruption of delivery at the option of the supplier.

Inter-utility transfer: A transfer of electric power between two or more electrical utilities. The NEB Part VI Regulations define five classes of inter-utility transfer. These are:

(1) Adjustment transfer: A transfer of electric power or energy made: (a) to adjust an energy account balance; (b) to compensate for electrical losses; (c) to compensate for services rendered; (d) to deliver output entitlements; or (e) to provide upstream or downstream benefits.

(2) Carrier transfer: A transfer of electric power or energy by one utility over the circuits of another, for delivery either to a third party or back to the originating utility.

(3) Equichange transfer: An interchange of equal quantities of electric power or energy within a stated period.

(4) Sale transfer: A transfer of electric power or energy under a contract of sale.

(5) Storage transfer: An electric energy transfer "banked" for the time being in the form of water in the reservoir space of another electrical utility, in the expectation that equivalent electric energy will be returned at a later time.

Isolated system: An electric power system not interconnected with any other system (such as the Northern Canada Power Commission). Isolated systems are usually of relatively small capacity.

Licence: A licence to export electricity from Canada, issued under Part VI of the National Energy Board Act, following a public hearing. A licence is subject to the approval of the Governor in Council.

Load: A curve for a specified period (such as a day, month or year) showing the amount of time during that period that the power load exceeded different values or different percentages of the maximum value.

Load curve (shape): The pattern of electricity use or production when demand is plotted against time.

Load factor: The ratio of the average load during a designated period to the peak or maximum load in that same period, usually expressed as a percentage of the peak load. The annual load factor for the entire Ontario Hydro system is about 68%.

Load rejection (load shedding): Interrupting the supply of electricity to a selected region or group of customers as a means of preserving the continuing safe operation of the remainder of a power system. This action is sometimes taken in an emergency when the total system load exceeds the the capacity of the generation available to supply it.

Load shifting: Shifting electrical demand from one period to another, usually from high-load to low-load periods.

Locked-in energy: Energy production capability at a generating station which cannot be used because of inadequate transmission capability connecting the generating station to the load. For example, part of the generating capacity of the Bruce Nuclear Generating Station is locked in.

Losses: Energy or power lost in circuits or equipment, mainly in the form of heat, when current flows through the circuit.

Marginal cost: The cost of supplying an additional unit of output. When the extra unit of output can be supplied simply by increasing production from the existing plant, it is usually specified as the "short-run marginal cost" or "incremental cost"; when new plant is required to supply the additional production, it is usually termed the "long-run marginal cost".

Marginal cost pricing: A rate structure in which prices are set at the cost of the last (marginal) unit of production, rather than at cost of production averaged over all output.

Mothball: To take equipment that is surplus to current needs or that has reached the end of its normal life and retain it in a preserved state. Mothballed equipment is not available for immediate use but can, with preparation, be resurrected for future use.

Name-plate rating: The full-load continuous rating of a generator or other electrical equipment under the conditions designated by the manufacturer, as indicated on the name plate attached to the device.

Outage: The state of any circuit component when it is not available to perform its intended function because of some event associated with that component. An outage may or may not cause an interruption of service to customers, depending on the layout of the system.

Parallel power: Independent generation which is linked to and synchronized with the bulk electricity system.

Peak demand: The maximum load consumed by a customer, group of customers or by the entire system in a stated period of time, such as a year.

Peak period: Periods during which relatively high demands are placed on an electrical system, as opposed to off-peak periods.

Peaking unit: A generating unit intended to be operated intermittently to supply peak loads.

Power pool: A grouping of two or more interconnected electric systems planned and operated to supply power in the most reliable and economical manner for their combined load requirements.

Power system: All the interconnected facilities of an electrical utility. A power system includes the generating stations, transformers, switching stations, transmission lines, substations, distribution lines, and circuits to the customers' premises; that is, all the facilities required to provide electrical services to the customers.

Primary energy source: The source of primary energy from which electricity is generated, including falling water, uranium (by nuclear fission), coal, oil, natural gas, wind, biomass, direct solar radiation, geothermal energy and tidal energy.

Prime mover: The turbine or engine that drives an electrical generator.

Pumped storage: An arrangement in which water is pumped from a lower to a higher reservoir, during off-peak hours. During peak hours, the water is allowed to return to the lower reservoir through hydro-electric turbines, thus generating power. Usually the turbines are reversible so that they can also serve as the pumps in the system.

Renewable energy source: A source of energy which is inherently self-renewing, such as the various manifestations of solar energy (water power, biomass, wind energy, direct solar radiation, wave energy and ocean currents), tidal energy and geothermal energy.

Reserve (generating) capacity: The extra generating capacity required on any power system over and above the expected peak load. Such a reserve is required for two main reasons: in case of the unexpected breakdown of generating equipment; and in case the actual peak load is higher than forecast.

Right-of-way: The strip of land on which a power line is located, and on which the power company has acquired the legal right to perform construction and maintenance, to restrict the growth of vegetation, and sometimes to restrict construction by other parties. The width of the right-of-way varies with line voltage.

Run-of-the-river plant: A hydro-electric generating station having negligible capacity for the storage of water, so that the plant has to run on the natural flow of the river. The output of the plant may therefore be subject to considerable variation.

Scheduled maintenance: Maintenance of equipment performed in accordance with a prearranged schedule.

Seasonal diversity: The diversity between loads that reach their maximum values at different seasons of the year. For example, most Canadian power systems experience their annual peak loads in the winter, whereas many U.S. systems have their annual peaks in the summer because of air conditioning. Systems that differ in this way can effect economies of scale by exchanging energy on a seasonal basis.

Service area: The area within which a utility is required, or has the right, to serve consumers.

Short-term power: Power and associated energy which one utility purchases from another for the purpose of obtaining a supply of power intended to be available at all times during the period covered by the commitment.

Social benefits: Benefits, whether tangible or intangible, resulting from a project. Social benefits are distinguishable from private benefits in that they include all the benefits of a project, whether or not they accrue to project sponsors.

Social costs: Costs or damages, whether tangible or intangible, which a project causes to be imposed. Social costs are distnguishable from private costs in that they include all the costs of a project incurred by all citizens rather than those only incurred by the project sponsors.

Spinning reserve: That portion of the reserve generating capacity which is actually in service, connected to the system, spinning (but not generating full power), and which is ready to pick up load automatically at a moment's notice.

Split savings: A widely-used formula for the pricing of energy, especially economy energy sold by one utility to another, in which the total saving resulting from a sale is split equally between buyer and seller.

Stability: The ability of power systems to remain in synchronism.

Station service: The electricity required at a generating station to run the auxiliary plant plus the capacity represented by the losses in the generator transformers.

Storage: The water held in a reservoir. Storage is used to even out the natural variations of flow in a river, so that the ouput of hydro-electric generation can be made as independent as possible of such natural variations.

Strategic conservation: Efficiency improvements which would not be undertaken by customers based only on the value of the savings available to them. Additional financial or other incentives, or the removal of barriers by the utility or by government, are required to promote the conservation initiative.

Substation: A station at which the voltage of the bulk power system is stepped down to a level suitable for distribution, and at which the feeders at this lower voltage originate and may be switched on or off.

Sulphur dioxide: A heavy, odourless, suphocating gas with the chemical formula SO_2. It occurs in the flue gases emitted from furnaces where fuel is burned, including thermal generating stations. Combining with water vapour in the atmosphere, and in the presence of sunlight, it produces sulphuric acid and together with other acids leads to the phenomenon of acidic precipitation.

Summer peak: The highest load on a power system during the summer, usually caused by air conditioning in hot weather.

Superconductor: An electrical conductor offering negligible resistance to the flow of electricity.

Surplus energy: Energy that is surplus to the needs of its owner, including both load and reserve. Surplus energy can be produced whenever the total generating capacity exceeds the total load, and is often sold on an interruptible basis.

Switching station: A station at which the transmission lines of a power system can be selectively connected or disconnected by means of switchgear.

Synchronism: The condition of alternating current generators being "in phase"; that is, timed so that their voltage waves reach the maximum and minimum values at exactly the same instant. This is an essential condition in order for alternating current generators to operate on the same system.

Synchronous tie: Any alternating current tie line. All generating units interconnected by the tie must be in synchronism.

Thermal generating station: An electric generating station where the prime movers are driven by gases or steam produced by burning fuels (such as coal, oil, gas, wood or refuse) or by nuclear processes.

Time-of-use (time-differentiated) rates: Rates which vary based on the time of day, day of the week, or season of the year.

Transformer: An electromagnetic device for raising or lowering the voltage of alternating current electricity.

Transmission line: A line used for the transmission of electric power at high voltage. Transmission lines may be constructed overhead, underwater or underground. Lines of voltage less than 115 kilovolts are usually considered to be subtransmission or distribution.

Transmission system: Lines, transformers, switches, etc. used to transport electricity in bulk from sources of supply to other principal parts of the system. Transmission is generally at voltages of 115 kilovolts and above.

Turbine (hydraulic): A rotary type of prime mover in which mechanical energy is produced by the force of water, steam or gas directed against blades fastened to a rotating shaft.

Ultra high voltage (UHV): Any voltage in excess of approximately 1,000 kilovolts.

Voltage: The electrical force, measured in volts or multiples of volts (e.g. kilovolts) that causes a current to flow in a circuit. In North America, the standard voltage for residential use is 115 volts, with 230 volts used for heavy appliances such as ranges, dryers and hot water heaters. Voltages used for urban and rural distribution range from about 4 kV to 44 kV. The most common transmission voltages are 115, 132, 230, 345, 500 and 735 kV. The higher the voltage, the more power a transmission line can carry.

Wheeling: The transmission of power belonging to one utility through the circuits of another utility, for delivery either to a third party or back to the originating system.

Winter peak: The highest load on a power system during the six-month period October to March. In Canada, the winter peak almost always occurs in December or January.

Terminology: Nuclear Power

Actinides: A series of elements with atomic numbers of 89 or above and with similar chemical properties. The series includes such naturally occurring elements as thorium and uranium, together with the induced "transuranic" elements such as plutonium and americium. Among their isotopes are long-lived alpha emitters which must be taken into account in radioactive waste disposal.

Boiling water reactor: A reactor in which water is used as coolant and moderator and allowed to boil in the core.

Breeder reactor: A reactor which produces a fissile substance from a fertile substance, in greater quantity than the fissile substance being consumed in reactor operation (that is, with a conversion or "breeding" ratio greater than one).

CANDU: A family of nuclear fission reactors developed in Canada that uses natural uranium as the fuel and heavy water as the moderator and coolant.

Coolant: A liquid or gas circulated through or around the core of a reactor to remove heat.

Critical: A reactor is said to be "critical" when the rate of neutron production is exactly equal to the rate of neutron disappearance; that is, when the neutron multiplication factor equals one. If the multiplication factor exceeds one, the reactor is "supercritical"; if the factor is less than one, the reactor is "subcritical".

Critical mass: The minimum mass of fissile material with a specified configuration, material composition and environment that can sustain a critical chain reaction.

Emergency shutdown (scram): The act of shutting down a reactor suddenly to prevent or minimize a dangerous condition.

Enriched uranium: Uranium in which the percentage of the fissionable isotope uranium-235 has been increased beyond the 0.71% share that it comprises of naturally occurring uranium.

Fast reactor: A reactor in which nuclear fission is induced predominantly by fast neutrons.

Fertile material: Isotopes capable of being readily transformed, directly or indirectly, into fissionable material by the absorption of neutrons (particularly uranium-238 and thorium-232).

Fissile material: Nuclides readily fissioned by slow neutrons (for example, uranium-235, uranium-233, plutonium-239 and plutonium-241).

Fission energy: The energy released when an atom is split.

Fission products: Nuclides produced either by fission or by the subsequent radioactive decay of the nuclides thus formed.

Fuel cycle: The sequence of steps – such as fuel fabrication, utilization, reprocessing, refabrication and reutilization – through which nuclear fuel may pass.

Fuel inventory: The total amount of nuclear fuel invested in a reactor, a group of reactors or an entire fuel cycle.

Fuel reprocessing: The processing of nuclear fuel after its use in a reactor, to remove fission products and recover fissile and fertile material.

Gas-cooled reactor: A reactor in which a gas is used as coolant and graphite as moderator. The gas-cooled reactor, sometimes referred to as the "Magnox" type, uses natural uranium; the "advanced gas-cooled reactor" (AGR) and the "high-temperature gas-cooled reactor" (HTGR) require enriched fuel.

Half-life: The time taken for half of the atoms in a radioactive substance to spontaneously disintegrate, and hence for the activity to decay to half of its original value.

Heavy water: Deuterium oxide or D_2O. Heavy water is water in which the hydrogen atom is represented by the hydrogen isotope deuterium. It is used in an essentially pure state as both moderator and coolant in the CANDU reactor system.

Heavy water reactor: A reactor that uses heavy water as the moderator. The coolant may be gas, light water or heavy water (as in the CANDU system). Depending on the type, the fuel may be either natural or enriched uranium.

Isotope: Nuclides having the same atomic number but different masses (mass being proportional to the total number of protons and neutrons in the nucleus). For example, the element hydrogen, atomic number 1, can occur in three isotopes: common hydrogen or protium (with one proton in the nucleus); deuterium (with one proton and one neutron); and tritium (with one proton and two neutrons), which is unstable.

Light water reactor: A reactor in which ordinary (light) water serves as coolant and moderator. The BWR and PWR are examples of light water reactor systems.

Moderator: A material used to reduce neutron energy (that is, to produce "slow" or thermal neutrons) by scattering and slowing without excessive neutron capture.

Natural uranium: Uranium with the naturally occurring mixture of isotopes (99.28% fertile uranium-238, 0.71% fissile uranium-235 and 0.006% uranium-234).

Nuclear fission: The division of a heavy nucleus into two (or, rarely, more) parts, usually accompanied by the emission of neutrons, gamma radiation and energy release.

Nuclear fuel: A substance containing one or more fissile nuclides capable of maintaining a chain reaction in a reactor. The term may also be used to include a substance containing one or more fertile nuclides that can be transmuted into such fissile nuclides.

Nuclear power: Power generated at a station where the steam to drive the turbines is produced by the process of atomic fission, rather than by burning a combustible fuel.

Nuclear (fission) reactor: A device in which a self-sustaining nuclear fission chain reaction can be maintained and controlled. The term "nuclear reactor" is sometimes applied to a device in which a nuclear fusion reaction can be produced and controlled (fusion reactor).

Nuclide: An individual atomic species. Deuterium and tritium, although they are both isotopes of hydrogen, are two different nuclides.

Power reactor: A nuclear reactor whose primary purpose is to produce energy. Reactors in this class include electric power reactors, heat-producing reactors (producing heat for industrial processing, to supply district heating systems, etc.), and propulsion reactors in nuclear-powered surface vessels and submarines.

Radioactive waste: Unwanted radioactive materials obtained in the processing, handling or utilization of radioactive substances. Such wastes may be classified according to their degree of activity or to their half-lives, as follows.

A. According to the radionuclide content:

high-level waste: the highly radioactive liquid separated during the chemical reprocessing of irradiated fuel; or irradiated reactor fuel if it is not foreseen that the spent fuel will be reprocessed; or any other waste with a comparable radioactivity level.

intermediate-level waste: waste of a lower radioactivity level than high-level waste, but which still requires shielding during handling.

low-level waste: waste which does not require shielding during normal handling because of its low radionuclide content.

B. According to the half-life of the radioactive waste:

long-lived waste: waste that will not decay to an acceptable activity level in a period of time during which administrative controls can be expected to last.

short-lived waste: waste which will decay to a level considered to be insignificant from a radiological viewpoint, in a time period during which administrative controls can be expected to last. In some jurisdictions, radionuclides with a half-life of less than 30 years are considered to fall into this category.

Radioactive waste management: All activities, administrative and operational, that are involved in the handling, treatment, conditioning, transportation, storage and disposal of radioactive waste.

Radioactivity: The property of certain nuclides of spontaneously emitting particles or gamma radiation from their nucleus, of undergoing spontaneous fission, or of emitting X-radiation.

Thermal reactor: A reactor in which fission is induced predominantly by thermal or "slow" neutrons.

Selected References

(1) Ahearne, John F., "A Comparison of Nuclear Power Regulation in Canada and the United States", *The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review. Selected Consultants' Reports*, Ontario Nuclear Safety Review, Toronto, 29 February 1988.

(2) Aikin, A.M., J.M. Harrison and F.K. Hare, *The Management of Canada's Nuclear Wastes*, Report EP 77–6, Energy Policy Sector, Energy, Mines and Resources, Ottawa, 31 August 1977.

(3) American Nuclear Energy Council, *Report to Members and the 100th Congress*, Washington, undated.

(4) Bothwell, Robert, *Nucleus: The History of Atomic Energy of Canada Limited*, University of Toronto Press, Toronto, 1988.

(5) Boulton, J. (ed.), *Management of Radioactive Fuel Wastes: The Canadian Disposal Program*, AECL–6314, Whiteshell Nuclear Research Establishment, Research Company, Atomic Energy of Canada Limited, Pinawa, Manitoba, October 1978.

(6) Broad, L.G., *Douglas Point: Summary of Decommissioning to Date*, Atomic Energy of Canada Limited, 1 October 1986.

(7) Breest, H.-Ch., *Nuclear Energy in the Federal Republic of Germany*, Edition No. 101, Federal Ministry for Environment, Nature Conservation and Nuclear Safety, Federal Republic of Germany, March 1988.

(8) Brooks, G.L. and R.S. Hart, *The CANDU 300 Reactor System*, CANDU Operations, Atomic Energy of Canada Limited, Mississauga, Ontario, February 1988.

(9) Canada, Atomic Energy Control Board, *Annual Report 1987-88*, Ottawa, 1988.

(10) Canada, Atomic Energy Control Board, *Estimating the Costs of AECB Regulation*, INFO–0023–2, study performed by SECOR Inc. of Montreal, Ottawa, April 1981.

(11) Canada, Atomic Energy Control Board, *Regulation of Nuclear Activities in Canada*, INFO–0108, Ottawa, 5 December 1983.

(12) Canada, Atomic Energy Control Board, *Regulatory Policy Statement: Regulatory Objectives, Requirements and Guidelines for the Disposal of Radioactive Wastes – Long-Term Aspects*, Regulatory Document R–104, Ottawa, 5 June 1987a.

(13) Canada, Atomic Energy Control Board, *The Accident at Chernobyl and Its Implications for the Safety of CANDU Reactors*, INFO–0234(E), Ottawa, May 1987b.

(14) Canada, Atomic Energy of Canada Limited, *Nuclear Sector Focus*, Corporate Public Affairs, Ottawa, September 1987.

(15) Canada, Atomic Energy of Canada Limited, CANDU Operations, *CANDU in Canada's Future: A 30-year Vision. A Summary Document"*, Mississauga, Ontario, May 1988a.

(16) Canada, Atomic Energy of Canada Limited, CANDU Operations, *CANDU 300 Technical Highlights*, Mississauga, Ontario, undated.

(17) Canada, Atomic Energy of Canada Limited, CANDU Operations, *Presentation to the Standing Committee on Energy, Mines and Resources by CANDU Operations at Sheridan Park*, Mississauga, Ontario, 22 March 1988b.

(18) Canada, Atomic Energy of Canada Limited, CANDU Operations, "The Douglas Point Story", *Power Projections* (Special Edition), June 1984.

(19) Canada, Atomic Energy of Canada Limited, Quebec Operations and Hydro-Québec, Vice-présidence Information, Direction Édition et Production, *Cobalt–60: The Future Is Today*, Montreal, 1987.

(20) Canada, Atomic Energy of Canada Limited, Radiochemical Company, *World List of Industrial Gamma Irradiators*, Kanata, Ontario, March 1986.

(21) Canada, Atomic Energy of Canada Limited, Research Company, *Acoustic Borehole Meter*, Chalk River Nuclear Laboratories, Chalk River, Ontario, undated.

(22) Canada, Atomic Energy of Canada Limited, Research Company, *Eddy Current Probes*, Chalk River Nuclear Laboratories, Chalk River, Ontario, March 1987a.

(23) Canada, Atomic Energy of Canada Limited, Research Company, "AECL Assists U.S. Space Program", *Labstracts*, vol. 2, no. 6, June 1987b.

(24) Canada, Atomic Energy of Canada Limited, Research Company, *TASCC*, Chalk River Nuclear Laboratories, Chalk River, Ontario, 1987c.

(25) Canada, Energy, Mines and Resources, *Nuclear Industry Review: Problems and Prospects 1981-2000*, Ottawa, 1982.

(26) Canada, Energy, Mines and Resources, *Nuclear Policy Review: Background Papers*, Report No. ER81–2E, Ottawa, 1981.

(27) Canada, External Affairs, Canadian Embassy, Paris, *Visit to France of House of Commons Committee on Energy, Mines and Resources*, Briefing Book, April 1988.

(28) Canada, House of Commons, Standing Committee on Energy, Mines and Resources, *Oil – Scarcity or Security?*, Ottawa, September 1987.

(29) Canada, House of Commons, Standing Committee on Environment and Forestry, *High-Level Radioactive Waste in Canada: The Eleventh Hour*, Ottawa, January 1988.

(30) Canada, Science Council, *Food Irradiation: Prospects for Canadian Technology Development*, Statement, Ottawa, April 1987.

(31) Canadian Fusion Fuels Technology Project, *Fusion Energy and Canada's Role*, undated.

(32) Clegg, L.J. and J.R. Coady, *Radioactive Decay Properties of CANDU Fuel. Volume 1: The Natural Uranium Fuel Cycle*, AECL–4436/1, Whiteshell Nuclear Research Establishment, Atomic Energy of Canada Limited, Pinawa, Manitoba, January 1977.

(33) "Disallowances by State Regulators for Nuclear Units (1980-1986)", *Nuclear Industry*, March/April 1968, p. 64.

(34) Denault, Paul and Pabrita L. De, "Gentilly 1 Nears 'Static State'", *Nuclear Engineering International* (reprint), August 1985.

(35) Duke Power Company, *1987 Annual Report*, Charlotte, North Carolina, 1988.

(36) Dyring, Eric, "Sweden after Chernobyl: Revival of the Nuclear Power Debate", *Current Sweden*, No. 354, March 1987.

(37) Edin, Karl-Axel, "Sweden after Chernobyl: Consequences of the Nuclear Accident", *Current Sweden*, No. 353, February 1987.

(38) Eisberg, Robert and Robert Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*, John Wiley & Sons, Toronto, 1974.

(39) Électricité de France, *Technical Operation Results 1987*, Paris, January 1988.

(40) Électricité de France, *The French Nuclear Electricity Program*, Paris, 1986.

(41) Eldorado Resources Limited, *Uranium and Electricity*, 5th Edition, Ottawa, August 1985.

(42) Federal Republic of Germany, Federal Ministry of Environment, Nature Conservation and Nuclear Safety, *Nuclear Safety Regulations in the Federal Republic of Germany*, Edition No. 134, April 1988.

(43) Federal Republic of Germany, Federal Ministry for Research and Technology, *Fourth Nuclear Program 1973 to 1976 of the Federal Republic of Germany*, Bonn, 1974

(44) Federal Republic of Germany, Physikalisch-Technische Bundensanstalt, *Final Disposal of Radioactive Waste*, No. 9, Braunschweig, October 1985.

(45) Framatome, *Annual Report 1986*, Paris, June 1987.

(46) Framatome, *Visit to France of a Canadian Delegation Led by Mrs. Barbara Sparrow*, Briefing Notes, Paris, 14 April 1988.

(47) France, Commissariat à l'Énergie Atomique, Agence Nationale pour la gestion des Déchets Radioactifs, *ANDRA: A Government Agency for Safe Radioactive Waste Management*, Paris, undated.

(48) France, Commissariat à l'Énergie Atomique, *Les Centrales Nucléaires dans le Monde*, 1987 Edition, Paris, 1987.

(49) Gentner, N.E. and D.P. Morrison, "Detection and Impact on Cancer Causation of Persons Exhibiting Abnormal Susceptibility to Carcinogenic Agents", Toxicology Workshop, Chalk River Nuclear Laboratories, Chalk River, Ontario, 3 November 1987.

(50) Gordon, Joshua *et al*, *1986 Nuclear Power Safety Report*, Public Citizen, Critical Mass Energy Group, Washington, D.C., September 1987.

(51) Grisdale, Margaret C., "The Safety Implications of the Legal, Regulatory, and Organisational Framework Within Which Ontario's CANDU Reactors Operate", *The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review. Vol. 2 Appendices*, Appendix VII, Ontario Nuclear Safety Review, Toronto, 29 February 1988.

(52) Harvie, J.D., *Costs and Benefits of Nuclear Regulation in Canada*, Atomic Energy Control Board, Ottawa, 3 June 1985.

(53) Howles, Laurie, "Nuclear Station Achievement 1987", *World Nuclear Industry Handbook 1988*, Nuclear Engineering International, Sutton, England, 1988, p. 19-22.

(54) Hubbert, M. King, "Energy Resources" in *Resources and Man*, National Academy of Sciences-National Research Council, Committee on Resources and Man, W.H. Freeman and Company, San Francisco, 1969.

(55) Japan, Atomic Energy Commission, *Long-Term Program for Development and Utilization of Nuclear Energy*, 22 June 1987.

(56) Japan Industrial Location Center, *Nuclear Power Plants Siting in Japan*, Tokyo, March 1988.

(57) Kay, Charles E., "Statement before the Committee on Appropriations, Subcommittee on Energy and Water Development", Office of Civilian Radioactive Waste Management, Department of Energy, Washington, D.C., 17 March 1988.

(58) Kehoe, Keiki and Kathleen Welch, *$100 Billion in Contracts: Not a Penny at Risk. The Safety Implications of the Price-Anderson Act on the Department of Energy's Nuclear Contractors*, Environmental Policy Institute and U.S. Public Interest Research Group, Washington, D.C., February 1988.

(59) Kehoe, Keiki *et al*, *From Contact Lenses to Cornfields: The Public Is Not Protected. A Study of Nuclear Insurance in America*,a joint report of the Environmental Policy Institute, the U.S. Public Interest Research Group and the Union of Concerned Scientists, Washington, D.C., 28 September 1986.

(60) Kriesberg, Joseph, *Shutdown Strategies: Citizen Efforts To Close Nuclear Power Plants*, Public Citizen, Critical Mass Energy Project, Washington, D.C., undated.

(61) Kriesberg, Joseph, *Too Costly To Continue: The Economic Feasibility of a Nuclear Phase-Out*, Public Citizen, Critical Mass Energy Project, Washington, D.C., November 1987.

(62) Kriesberg, Joseph and Kenneth Boley, *Nuclear Lemons: An Assessment of America's Worst Commercial Nuclear Reactors*, Public Citizen, Critical Mass Energy Project, Washington, D.C., April 1988.

(63) Leclercq, Jacques, *The Nuclear Age*, Hachette, Paris, 1986.

(64) Lennox, Frank H. and Mark P. Mills, *Electricity from Nuclear Energy, Burden or Bargain? An Analysis of the Cost of Nuclear Electricity Versus Oil-Priced and Non-Utility Electricity*, Science Concepts, Inc., Washington, D.C., March 1988a.

(65) Lennox, Frank H. and Mark P. Mills, *The Cost of Turning Off U.S. Nuclear Electricity Plants*, Science Concepts, Inc., Washington, D.C., April 1988b.

(66) Lortie, Pierre and Robin Schweitzer, *A Strategy for the Development and Strengthening of the Canadian Nuclear Industry*, Final Report, SECOR Inc., Montreal, 23 March 1981.

(67) Lynch, G.F., *SLOWPOKE Energy System: Nuclear Technology in Local Energy Supply*, Local Energy Systems Business Unit, Whiteshell Nuclear Research Establishment, Atomic Energy of Canada Limited, Pinawa, Manitoba, February 1988.

(68) Lynch, G.F., *SLOWPOKE – Its Application to District Heating*, AECL–9515, Chalk River Nuclear Laboratories, Atomic Energy of Canada Limited, Chalk River, Ontario, July 1987.

(69) Lynch, G.F. *et al*, *Unattended Nuclear Systems for Local Energy Supply*, Paper 4.2.2.2, 13th Congress of the World Energy Conference, Cannes, France, 5-11 October 1986.

(70) Lyon, Robert and Marvis Tutiah, *Nuclear Fuel Waste Management: Protecting the Future*, WNRE 2–500, Nuclear Information Series, Whiteshell Nuclear Research Establishment, Atomic Energy of Canada Limited, Pinawa, Manitoba, January 1984.

(71) MacGregor, Sam, *Bruce Energy Centre: Status as at July 23, 1987*, RESOLUTE Development Corp., Kincardine, Ontario, undated.

(72) Mears, Dan, "Modular High Temperature Gas-Cooled Reactor: An Attractive Second Generation Nuclear Option Designed To Meet Utility/User Needs", presentation by Gas-Cooled Reactor Associates to the U.S. Council on Energy Awareness, the Nuclear Management and Resources Council and the American Nuclear Energy Council, 17 March 1988.

(73) Meneley, Daniel A., "Ontario Hydro's CANDU Nuclear Stations: An Outline of Safety-related Design Aspects" in Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review. Vol. 2 Appendices*, Appendix I, Toronto, 29 February 1988, p. I/2.

(74) "Nuclear Energy After Chernobyl: Views from Four Countries", *The Energy Journal*, Vol. 9, No. 1, January 1988, p. 27-39.

(75) Nuclear Engineering International, "Reactor Statistics", *World Nuclear Industry Handbook 1988*, Reed Business Publishing, Sutton, England,1988.

(76) Ontario Hydro, *Annual Report 1987*, Toronto, April 1988a.

(77) Ontario Hydro, *Economics of CANDU–PHW – 1985*, NGD–10, Toronto, August 1986a.

(78) Ontario Hydro, *Heavy Water*, Toronto, undated.

(79) Ontario Hydro, *Inside Hydro*, Corporate Relations Branch, Toronto, December 1987a.

(80) Ontario Hydro, *Meeting Future Energy Needs: Draft Demand/Supply Planning Strategy*, Report 666 SP and Report 666A SP (Supplementary Documents), System Planning Division, Toronto, December 1987b.

(81) Ontario Hydro, *Ontario Hydro CANDU Operating Experience*, NGD–9, Toronto, 1986b.

(82) Ontario Hydro, "Ontario Hydro Submits Environmental Assessment for Acid Gas Scrubbers", Media Relations, Toronto, 15 February 1988b.

(83) Ontario Hydro, "Retubing Announced at Pickering Units 3&4", Media Relations, Toronto, 16 March 1988c.

(84) Ontario, Legislative Assembly, Select Committee on Ontario Hydro Affairs, *The Management of Nuclear Fuel Waste – Final Report*, Toronto, June 1980.

(85) Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review. A Submission to the Ontario Nuclear Safety Review by Atomic Energy of Canada Limited*, Toronto, 29 February 1988a.

(86) Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review. Ontario Hydro Submission to the Ontario Nuclear Safety Review*, Toronto, 29 February 1988b.

(87) Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review. Report to the Minister*, F. Kenneth Hare, Commissioner, Toronto, 29 February 1988c.

(88) Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review. Vol. 1 Report to the Minister, Technical Report and Annexes*, F. Kenneth Hare, Commissioner, Toronto, 29 February 1988d.

(89) Ontario, Royal Commission on Electric Power Planning, *A Race Against Time: Interim Report on Nuclear Power in Ontario*, September 1978.

(90) Ontario, Royal Commission on Electric Power Planning, *The Report of the Royal Commission on Electric Power Planning*, Volumes 1-9, Toronto, February 1980.

(91) Organisation for Economic Co-operation and Development, Nuclear Energy Agency, *Decommissioning of Nuclear Facilities: Feasibility, Needs and Costs*, Paris, 1986a.

(92) Organisation for Economic Co-operation and Development, Nuclear Energy Agency, *Nuclear Spent Fuel Management: Experience and Options*, Paris, 1986b.

(93) Organisation for Economic Co-operation and Development, Nuclear Energy Agency, *Projected Costs of Generating Electricity from Nuclear and Coal-Fired Power Stations for Commissioning in 1995*, Paris, 1986c.

(94) Pannell, B.J. and F.R. Campbell, *Three Mile Island – A Review of the Accident and Its Implications for CANDU Safety*, INFO–0003, Atomic Energy Control Board, Ottawa, March 1980.

(95) Price-Anderson Campaign, "Floor Vote Briefing Packet", Washington, D.C., 25 January 1988 plus update.

(96) Rheinisch-Westfälisches Elektrizitätswerk, *Annual Report and Accounts 1986/87*, Essen, February 1988.

(97) Robertson, J.A.L., *Nuclear Energy in Canada: The CANDU System*, AECL–6328(Rev.1), CANDU Operations, Atomic Energy of Canada Limited, Ottawa, July 1984.

(98) Söderberg, Olof, "Organizing Nuclear Waste Management – The Swedish Approach", paper presented at the symposium The Back-End of the Fuel Cycle, Munich May 18-21, 1987.

(99) Sweden, Kärnkraftsäkerhet och Utbildning AB, *Summary of Operating Experience at Swedish Nuclear Power Plants – 1987*, Stockholm, February 1988.

(100) Sweden, Ministry of Industry, *Guidelines for the Swedish Energy Policy: A Summary of the Government Bill Presented in February 1985*, Stockholm, 1986.

(101) Sweden, Ministry of Industry, *New Swedish Nuclear Legislation*, Ds I 1984:18, Stockholm, 1984.

(102) Sweden, Secretariat for Future Studies, *Energy in Transition: A Report on Energy Policy and Future Options*, Stockholm, 1977.

(103) Sweden, Statens kärnbränslenämnd, *Legal Documents on the Management of Spent Nuclear Fuel and Radioactive Waste in Sweden*, Stockholm, March 1987a.

(104) Sweden, Statens kärnbränslenämnd, *Management and Disposal of Spent Nuclear Fuel: Review of a Programme for Research, Development and Other Measures*, Stockholm, May 1987b.

(105) Sweden, Statens kärnkraftinspektion, *SKi Swedish Nuclear Power Inspectorate: A Presentation of Our Activities*, Stockholm, undated.

(106) Sweden, Statens strålskyddinstitut, *The Swedish National Institute of Radiation Protection*, Stockholm, 1987.

(107) Sweden, Studsvik Energiteknik AB, Studsvik Nuclear, *Waste Incineration Systems*, Nyköping, 1987.

(108) Sweden, Svensk Kärnbränslehantering AB, *Activities*, Stockholm, 1985.

(109) Sweden, Svensk Kärnbränslehantering AB, *Central Interim Storage Facility for Spent Nuclear Fuel – CLAB*, Stockholm, 1986.

(110) Sweden, Svensk Kärnbränslehantering AB, *Final Repository for Reactor Waste – SFR*, Stockholm, undated(a).

(111) Sweden, Svensk Kärnbränslehantering AB, *M/S Sigyn*, Stockholm, undated(b).

(112) Sweden, Svensk Kärnbränslehantering AB, *Stripa: A Deep Underground Research Facility for Nuclear Waste Disposal*, Stockholm, undated(c).

(113) Swedish Atomic Forum, *Nuclear Sweden VI*, Stockholm, undated.

(114) Thexton, H.E., "Canada" in *Nuclear Power: Policy and Prospects*, P.M.S. Jones (ed.), John Wiley & Sons, Toronto, 1987.

(115) Tin, E., *On-Site Dry Storage of the Douglas Point Spent Fuel in Concrete Canisters*, CANDU Operations, Atomic Energy of Canada Limited, Mississauga, January 1988.

(116) Tong, L.S. and Joel Weisman, *Thermal Analysis of Pressurized Water Reactors*, 2nd edition, American Nuclear Society, 1979.

(117) United States, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *An Analysis of Nuclear Power Plant Operating Costs*, DOE/EIA–0511, Washington, D.C., 16 March 1988.

(118) United States, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Annual Outlook for U.S. Electric Power 1987: Projections through 2000*,DOE/EIA–0474(87), Washington. D.C., May 1987a.

(119) United States, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Commercial Nuclear Power 1987: Prospects for the United States and the World*, DOE/EIA–0438(87), Washington, D.C., July 1987b.

(120) United States, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Domestic Uranium Mining and Milling Industry: 1986 Viability Assessment*, DOE/EIA–0477(86), Washington, D.C., November 1987c.

(121) United States, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Electric Power Annual 1986*, DOE/EIA–0348(86), Washington, D.C., September 1987d.

(122) United States, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Historical Plant Cost and Annual Production Expenses for Selected Electric Plants 1985*, DOE/EIA–0455(85), Washington, D.C., June 1987e.

(123) United States, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Investor Perceptions of Nuclear Power*, DOE/EIA–0446, Washington, D.C., May 1984.

(124) United States, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Uranium Industry Annual 1986*, DOE/EIA–0478(86), Washington, D.C., October 1987f.

(125) United States, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *U.S.-International Electricity Trade: Projections through 1995*, DOE/EIA–0496, Washington, D.C., September 1986.

(126) United States, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *World Nuclear Fuel Cycle Requirements 1987*, DOE/EIA–0436(87), Washington, D.C., 27 August 1987g.

(127) United States, Department of Energy, Office of Civilian Radioactive Waste Management, *Answers to Your Questions on High-Level Nuclear Waste*, DOE/RW–0152, Washington, D.C., November 1987a.

(128) United States, Department of Energy, Office of Civilian Radioactive Waste Management, *Draft Mission Plan Amendment*, DOE/RW–0128, Washington, D.C., January 1987b.

(129) United States, Department of Energy, Office of Civilian Radioactive Waste Management, *Site Characterization Plan – Overview: Yucca Mountain Site, Nevada Research and Development Area, Nevada. Consultation Draft,* DOE/RW–0161, Washington, D.C., January 1988.

(130) United States, Federal Energy Regulatory Commission, *Administrative Determination of Full Avoided Costs, Sales of Power to Qualifying Facilities, and Interconnection Facilities*, Notice of Proposed Rulemaking, Washington, D.C., 16 March 1988a.

(131) United States, Federal Energy Regulatory Commission, *Regulations Governing Bidding Programs*, Notice of Proposed Rulemaking, Washington, D.C., 16 March 1988b.

(132) United States, Federal Energy Regulatory Commission, *Regulations Governing Independent Power Producers*, Notice of Proposed Rulemaking, Washington, D.C., 16 March 1988c.

(133) United States, Nuclear Regulatory Commission, Office of Public Affairs, "Disposal of Radioactive Waste", Washington, D.C., May 1983.

(134) United States, Nuclear Regulatory Commission, *Implications of the Accident at Chernobyl for Safety Regulation of Commercial Nuclear Power Plants in the United States: Draft for Comment*, NUREG–1251, Washington, D.C., August 1987a.

(135) United States, Nuclear Regulatory Commission, Office of Governmental and Public Affairs, "NRC Mission – To Protect Public Health and Safety", Washington, D.C., May 1987b.

(136) United States, Nuclear Regulatory Commission, Office of Public Affairs, "Price-Anderson Act", Washington, D.C., January 1983.

(137) United States, Nuclear Regulatory Commission, Office of Governmental and Public Affairs, *The Nuclear Regulatory Commission: Fact Sheet*, NUREG BR–0099, Rev. 2, Washington, D.C., undated.

(138) United States, The President's Commission on the Accident at Three Mile Island, *Report of The President's Commission on the Accident at Three Mile Island*, John G. Kemeney, Chairman, Washington, D.C., October 1979.

(139) U.S. Council on Energy Awareness, *Electricity from Nuclear Energy: 1988 Edition*, Washington, D.C., 1988a.

(140) U.S. Council on Energy Awareness, "Nuclear Energy at the Ballot Box: 13 Wins, No Losses", *Energy Update*, Washington, April 1988b, p. 1-2.

(141) Wargo, J.R., "Under the Microscope: The Future of the NRC", *Nuclear Industry*, March/April 1988, p. 41-51.

Pursuant to Standing Order 99(2), the Committee requests that the Government table a comprehensive response to its report.

A copy of the relevant Minutes of Proceedings and Evidence of the Standing Committee on Energy, Mines and Resources (*Issues Nos. 29, 30, 31, 32, 33, 34, 37, 38, 39, 40, 41, 42, 47 and 48, which includes this report*), is tabled.

Respectfully submitted,

Paul Gagn

for BARBARA SPARROW
Chairman

MINUTES OF PROCEEDINGS

TUESDAY, June 21, 1988
(76)

The Standing Committee on Energy, Mines and Resources met in camera at 8:20 o'clock a.m., in Room 306 West Block, this day, the Chairman, Barbara Sparrow, presiding.

Members of the Committee present: Paul Gagnon, Len Gustafson, Russell MacLellan and Barbara Sparrow.

In attendance: Dean Clay, Consultant; Lawrence Harris, Researcher.

The Committee resumed consideration of its draft report.

Agreed, - That the draft report be adopted as the Committee's Tenth Report to the House and that 3,500 extra copies be printed with a special cover.

Agreed, - That the Committee engage the services of an editor for the French version of the report.

Agreed, - That the Committee seek an Order of the House empowering it to table its Tenth Report with the Clerk of the House if the House is adjourned for the summer.

At 9:40 o'clock a.m., the Committee adjourned to the call of the Chair.

Eugene Morawski
Clerk of the Committee

PROCÈS VERBAUX

LE MARDI 21 juin 1988
(76)

Le Comité permanent de l'énergie, des mines et des ressources se réunit à huis clos, aujourd'hui à 8 h 20, dans la pièce 306 de l'édifice de l'Ouest, sous la présidence de Barbara Sparrow, (présidente).

Membres du comité présents: Paul Gagnon, Len Gustafson, Russell MacLellan et Barbara Sparrow.

Aussi présents: Dean Clay, conseiller; Lawrence Harris, attaché de recherche.

Le comité reprend l'étude de son projet de rapport.

Il est convenu, - Que le projet de rapport soit adopté en tant que Dixième rapport du comité à la Chambre, et que soient tirés 3 500 exemplaires dudit rapport, munis d'une couverture spéciale.

Il est convenu, - Que le comité retienne les services d'un éditeur pour la version française du rapport.

Il est convenu, - Que le comité obtienne de la Chambre un ordre lui permettant de déposer son Dixième rapport chez le greffier de la Chambre si celle-ci s'est prorogée.

À 9 h 40, le comité s'ajourne jusqu'à nouvelle convocation de la présidente.

Le greffier du Comité

Eugene Morawski

Conformément à l'article 99(2) du Règlement, le Comité demande que le gouvernement dépose une réponse globale au présent rapport.

Un exemplaire des Procès-verbaux et témoignages du Comité permanent de l'énergie, des mines et des ressources (*fascicules nos 29, 30, 31, 32, 33, 34, 37, 38, 39, 40, 41, 42, 47 et 48, qui contient ce rapport*) est déposé.

Respectueusement soumis,

La présidente,
BARBARA SPARROW

(138) États-Unis, The President's Commission on the Accident at Three Mile Island, *Report of The President's Commission on the Accident at Three Mile Island*, JohnG. Kemeney, Chairman, Washington, D.C., octobre 1979.

(139) U.S. Council on Energy Awareness, *Electricity from Nuclear Energy : 1988 Edition*, Washington, D.C., 1988a.

(140) U.S. Council on Energy Awareness, «Nuclear Energy at the Ballot Box : 13 Wins, No Losses», *Energy Update*, Washington, avril 1988b, p. 1-2.

(141) Wargo, J.R., «Under the Microscope : The Future of the NRC», *Nuclear Industry*, mars/avril 1988, p. 41-51.

(123) États-Unis, Department of Energy, energy Inforation Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Uranium Industry Annual 1986*, DOE/EIA-0478(86), Washington, D.C., October 1987f.

(124) États-Unis, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Uranium Industry Annual 1988*, DOE/EIA-0478(86), Washington, D.C., octobre 1987f.

(125) États-Unis, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *U.S.-International Electricity Trade : Projections through 1995*, DOE/EIA-0496, Washington, D.C., septembre 1986.

(126) États-Unis, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *World Nuclear Fuel Cycle Requirements 1987*, DOE/EIA-0436(87), Washington, D.C., août 1987g.

(127) États-Unis, Department of Energy, Office of Civilian Radioactive Waste Management, *Answers to Your Questions on High-Level Nuclear Waste*, DOE/RW-0152, Washington, D.C., novembre 1987a.

(128) États-Unis, Department of Energy, Office of Civilian Radioactive Waste Management, *Draft Mission Plan Amendment*, DOE/RW-0128, Washington, D.C., janvier 1987b.

(129) États-Unis, Department of Energy, Office of Civilian Radioactive Waste Management, *Site Characterization Plan — Overview : Yucca Mountain Site, Nevada Research and Development Area, Nevada*, DOE/RW-0161, Washington, D.C., janvier 1988.

(130) États-Unis, Federal Energy Regulatory Commission, *Administrative Determination of Full Avoided Costs, Sales of Power to Qualifying Facilities, and Interconnection Facilities*, Notice of Proposed Rulemaking, Washington, D.C., 16 mars 1988a.

(131) États-Unis, Federal Energy Regulatory Commission, *Regulations Governing Bidding Programs*, Notice of Proposed Rulemaking, Washington, D.C., 16 mars 1988b.

(132) États-Unis, Federal Energy Regulatory Commission, *Regulations Governing Independent Power Producers*, Notice of Proposed Rulemaking, Washington, D.C., 16 mars 1988c.

(133) États-Unis, Nuclear Regulatory Commission, Office of Public Affairs, «Disposal of Radioactive Waste», Washington, D.C., mai 1983.

(134) États-Unis, Nuclear Regulatory Commission, *Implications of the Accident at Chernobyl for Safety Regulation of Commercial Nuclear Plants in the United States : Draft for Comment*, NUREG-1251, Washington, D.C., août 1987a.

(135) États-Unis, Nuclear Regulatory Commission, Office of Governmental and Public Affairs, «NRC Mission — To Protect Public Health and Safety», Washington, D.C, mai 1987b

(136) États-Unis, Nuclear Regulatory Commission, Offie of Public Affairs, «Price-Anderson Act», Washington, D.C., janvier 1983.

(137) États-Unis, Nuclear Regulatory Commission, *The Nuclear Regulatory Commission : Fact Sheet*, NUREG BR-0099, Rev. 2, Office of Governmental and Public Affairs, Washington, D.C., non daté.

(105) Suède, Statens kärnbraänslenämnd, *SKi Swedish Nuclear Power Inspectorate : A Presentation of Our Activities*, Stockholm, non daté.

(106) Suède, Statens strâlskyddinstitut, *The Swedish National Institute of Radiation Protection*, Stockholm, 1987.

(107) Suède, Studsvik Energiteknik AB, Studsvik Nuclear, *Waste Incineration Systems*, Nyköping, 1987.

(108) Suède, Svensk Kärnbränslehantering AB, *Activities*, Stockholm, 1985.

(109) Suède, Svensk Kärnbränslehantering AB, *Central Interim Storage Facility for Spent Nuclear Fuel — CLAB*, Stockholm, 1986.

(110) Suède, Svensk Kärnbränslehantering AB, *Final Repository for Reactor Waste — SFR*, Stockholm, non daté (a).

(111) Suède, Svensk Kärnbränslehantering AB, *M/S Sigyn*, Stockholm, non daté (b).

(112) Suède, Svensk Kärnbränslehantering AB, *Stripa : A Deep Underground Research Facility for Nuclear Waste Disposal*, Stockholm, sans date (c).

(113) Suède, Forum atomique suédois, *Nuclear Sweden VI*, Stockholm, non daté.

(114) Thexton, H.E., «Canada» in *Nuclear Power : Policy and Prospects*, P.M.S. Jones (éd.), John Wiley & Sons, Toronto, 1987.

(115) Tin, E., *On-Site Dry Storage of the Douglas Point Spent Fuel in Concrete Canisters*, Exploitation CANDU, Énergie atomique du Canada, Limitée, Mississauga, Ontario, janvier 1988.

(116) Tong, L.S. et Joel Weisman, *Thermal Analysis of Pressurized Water Reactors*, 2e édition, American Nuclear Society, 1979.

(117) États-Unis, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric And Alternate Fuels, *An Analysis of Nuclear Power Plant Operating Costs*, DOE/EIA-0511, Washington, D.C., mars 1988.

(118) États-Unis, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Annual Outlook for U.S. Electric Power 1987 : Projections Through 2000*, DOE/EIA-0474(87), Washington, D.C., mai 1987a.

(119) États-Unis, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Commercial Nuclear Power 1987 : Prospects for the United States and the World*, DOE/EIA-0438(87), Washington, D.C., juillet 1987b.

(120) États-Unis, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Domestic Uranium Mining and Milling Industry : 1986 Viability Assessment*, DOE/EIA-0477(86), Washington, D.C., novembre 1987c.

(121) États-Unis, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Electric Power Annual 1986*, DOE/EIA-0348(88), Washington, D.C., septembre 1987d.

(122) États-Unis, Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, *Historical Plant Cost and Annual Production Expenses for Selected Electric Plants 1985*, DOE/EIS-0455(85), Washington, D.C., juin 1987e.

(87) Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors : A Scientific and Technical Review*. Report to the Minister, F. Kenneth Hare, Commissioner, Toronto, 29 février 1988c.

(88) Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors : A Scientific and Technical Review*. Vol. 1 Report to the Minister, Technical Report and Annexes, F. Kenneth Hare, Commissioner, Toronto, 29 février 1988d.

(89) Ontario, Royal Commission on Electric Power Planning, *A Race Against Time : Interim Report on Nuclear Power in Ontario*, septembre 1978.

(90) Ontario, Royal Commission on Electric Power Planning, *The Report of the Royal Commission on Electric Power Planning*, Volumes 1-9, Toronto, février 1980.

(91) Organisation de coopération et de développement économiques, Agence de l'énergie nucléaire, *Déclassement des installations nucléaires : Faisabilité, besoins et coûts*, Paris, 1986a.

(92) Organisation de coopération et de développement économiques, Agence de l'énergie nucléaire, *Gestion du combustible nucléaire irradié, expérience et options*, Paris, 1986b.

(93) Organisation de coopération et de développement économiques, Agence de l'énergie nucléaire, *Prévision des coûts de l'électricité produite par des centrales nucléaires ou au charbon mises en service en 1995*, Paris, 1986c.

(94) Pannell, B.J. et F.R. Campbell, *Three Mile Island — A Review of the Accident and Its Implications for CANDU Safety*, INFO-0003, Commission de contrôle de l'énergie atomique, Ottawa, mars 1980.

(95) Price-Anderson Campaign, «Floor Vote Briefing Packet», Washington, D.C., 25 janvier 1988 plus update.

(96) Rheinisch-Westfälisches Elektrizitätswerk, *Annual Report and Accounts 1986/87*, Essen, février 1988.

(97) Robertson, J.A.L., *L'énergie nucléaire au Canada : Le système CANDU*, AECL-6328(rév. 1), Exploitation CANDU, Énergie atomique du Canada, Limitée, Ottawa, juillet 1984.

(98) Söderberg, Olof, «*Organizing Nuclear Waste Management — The Swedish Approach*», communication présentée au colloque The Back-End of the Fuel Cycle, Munich, 18-21 mai 1987.

(99) Suède, Kärnkraftsäkerhet och Utbildning AB, *Summary of Operating Experience at Swedish Nuclear Power Plants — 1987*, Stockholm, février 1988.

(100) Suède, ministère de l'Industrie, *Guidelines for the Swedish Energy Policy : A Summary of the Government Bill Presented in February 1985*, Stockholm, 1986.

(101) Suède, ministère de l'Industrie, *New Swedish Nuclear Legislation*, Ds I 1984:18, Stockholm, 1984.

(102) Suède, Secrétariat de prospective, *Energy in Transition : A Report on Energy Policy and Future Options*, Stockholm, 1977.

(103) Suède, Statens kärnbranslenämnd, *Legal Documents on the Management of Spent Nuclear Fuel and Radioactive Waste in Sweden*, Stockholm, mars 1987a.

(104) Suède, Statens kärnbränslenämnd, *Management and Disposal of Spent Nuclear Fuel : Review of a Programme Reseach, Development and Other Measures*, Stockholm, mai 1987b.

(70) Lyon, Robert et Marvis Tutiah, *Nuclear Fuel Waste Management : Protecting the Future*, WNRE 2-500, Nuclear Information Series, Whiteshell Nuclear Research Establishment, AECL, Pinawa (Manitoba), janvier 1984.

(71) MacGregor, Sam, *Bruce Energy Centre : Status as at July 23, 1987*, RESOLUTE Development Corp., Kincardine, Ontario, non daté.

(72) Mears, Dan, «Modular High Temperature Gas-Cooled Reactor : An Attractive Second Generation Nuclear Option Designed To Meet Utility/User Needs», présentation de la Gas-Cooled Reactor Associates au U.S. Council on Energy Awareness, au Nuclear Management and Resources Council et au American Nuclear Energy Council, 17 mars 1988.

(73) Meneley, Daniel A., «Ontario Hydro's CANDU Nuclear Stations : An outline of Safety-related Design Aspects» in Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors : A Scientific and Technical Review*. Vol. 2 Appendices, Appendix 1, Toronto, 29 février 1988, p. 1/2.

(74) «Nuclear Energy After Chernobyl : Views from Four Countries», *The Energy Journal*, vol. 9, n° 1, janvier 1988, p. 27-39.

(75) Nuclear Engineering International, «Reactor Statistics», *World Nuclear Industry Handbook 1988*, Reed Business Publishing, Sutton, Angleterre, 1988.

(76) Ontario Hydro, *Annual Report 1987*, Toronto, avril 1988.

(77) Ontario Hydro, *Economics of CANDU-PHW — 1985*, NGD-10, Toronto, août 1986a.

(78) Ontario Hydro, *Heavy Water*, Toronto, non daté.

(79) Ontario Hydro, *Inside Hydro*, Corporate Relations Branch, Toronto, décembre 1987a.

(80) Ontario Hydro, *Meeting Future Energy Needs : Draft Demand/Supply Planning Strategy*, Report 666 SP et Report 666A SP (Supplementary Documents), System Planning Division, Toronto, décembre 1987.

(81) Ontario Hydro, *Ontario Hydro CANDU Operating Experience*, NGD-9, Toronto, 1986.

(82) Ontario Hydro, «Ontario Hydro Submits Environmental Assessment for Acid Gas Scrubbers», Media Relations, Toronto, 15 février 1988b.

(83) Ontario Hydro, «Retubing Announced at Pickering Units 3 & 4», Media Relations, Toronto, 16 mars 1988c.

(84) Ontario, Legislative Assembly, Select Committee on Ontario Hydro Affairs, *The Management Nuclear Fuel Waste — Final Report*, Toronto, juin 1980

(85) Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors : A Scientific and Technical Review*. A Submission to the Ontario Nuclear Safety Review by Atomic Energy of Canada Limited, Toronto, 29 février 1988a.

(86) Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors : A Scientific and Technical Review*. Ontario Hydro Submission to the Ontario Nuclear Safety Review, Toronto, 29 février 1988b.

(54) Hubbert, M. King, «Energy Resources» in *Resources and Man*, National Academy of Sciences-National Research Council, Committee on Resources and Man, W.H. Freeman and Company, San Francisco, 1969.

(55) Japon, Commission de l'énergie atomique, *Long-Term Program for Development and Utilization of Nuclear Energy*, 22 juin 1987.

(56) Japon, Centre de localisation industrielle, *Nuclear Power Plants Siting in Japan*, Tokyo, mars 1988.

(57) Kay, Charles E., «Statement before the Committee on Appropriations, Subcommittee on Energy and Water Development», Office of Civilian Radioactive Waste Management, Department of Energy, Washington, D.C., 17 mars 1988.

(58) Kehoe, Keiki et Kathleen Welch, *$100 Billion in Contracts : Not a Penny at Risk. The Safety Implications of the Price-Anderson Act on the Department of Energy's Nuclear Contractors*, Environmental Policy Institute et U.S. Public Interest Research Group, Washington, D.C., février 1988.

(59) Kehoe, Keiki et al., *From Contact Lenses to Cornfields : The Public is Not Protected. A Study of Nuclear Insurance in America*, rapport mixte du Environmental Policy Institute, du U.S. Public Interest Research Group et de la Union of Concerned Scientists, Washington, D.C., 28 septembre 1986.

(60) Kriesberg, Joseph, *Shutdown Strategies : Citizen Efforts To Close Nuclear Power Plants*, Public Citizen, Critical Mass Energy Project, Washington, D.C., non daté.

(61) Kriesberg, Joseph, *Too Costly To Continue : The Economic Feasability of a Nuclear Phase-Out*, Public Citizen, Critical Mass Energy Project, Washington, D.C., novembre 1987.

(62) Kriesberg, Joseph et Kenneth Boley, *Nuclear Lemons : An Assessment of America's Worst Commercial Nuclear Reactors*, Public Citizen, Critical Mass Energy Project, Washington, D.C., avril 1988.

(63) Leclercq, Jacques, *L'Âge nucléaire*, Hachette, Paris, 1986.

(64) Lennox, Frank H. et Mark P. Mills, *Electricity from Nuclear Energy, Burden or Bargain? An Analysis of the Cost of Nuclear Electricity Versus Oil-Priced and Non-Utility Electricity*, Science Concepts, Inc., Washington, D.C., mars 1988a.

(65) Lennox, Frank H. et Mark P. Mills, *The Cost of Turning Off U.S. Nuclear Electricity Plants*, Science Concepts, Inc., Washington, D.C., avril 1988b.

(66) Lortie, Pierre et Robin Schweitzer, *A Strategy for the Development and Strengthening of the Canadian Nuclear Industry*, rapport final, SECOR Inc., Montréal, 23 mars 1981.

(67) Lynch, G.F., *SLOWPOKE Energy System : Nuclear Technology in Local Energy Supply*, Local Energy Systems Business Unit, Société de recherche, Énergie atomique du Canada Limitée, février 1988.

(68) Lynch, G.F., *SLOWPOKE* — Its Application to District Heating, AECL-9515, Chalk River Nuclear Laboratories, Atomic Energy of Canada Limited, Chalk River, Ontario, juillet 1987.

(69) Lynch, G.F. et al, *Unattended Nuclear Systems for Local Energy Supply*, Paper 4.2.2.2, 13th Congress of the World Energy Conference, Cannes, France, 5-11 octobre 1986.

(36) Dyring, Eric, «Sweden after Chernobyl : Revival of the Nuclear Power Debate», *Current Sweden*, No. 354, mars 1987.

(37) Edin, Karl-Axel, «Sweden after Chernobyl : Consequences of the Nuclear Accident», *Current Sweden*, No. 353, février 1987.

(38) Eisberg, Robert et Robert Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles*, John Wiley & Sons, Toronto, 1974.

(39) Électricité de France, *Résultats techniques d'exploitation 1987*, Paris, janvier 1988.

(40) Électricité de France, *Le programme français d'électronucléaire*, Paris, 1986.

(41) Eldorado Ressources Limitée, *Uranium et électricité*, 5e édition, Ottawa, août 1985.

(42) République fédérale d'Allemagne, ministère fédéral de l'Environnement, Nature Conservation and Nuclear Safety, *Nuclear Safety Regulations in the Federal Republic of Germany*, Édition n° 134, avril 1988.

(43) République fédérale d'Allemagne, Federal Ministry for Research and Technology, *Fourth Nuclear Program 1973 to 1976 of the Federal Republic of Germany*, Bonn, 1974.

(44) Federal Republic of Germany, Physikalisch-Technische Bundensanstalt, *Final Disposal of Radioactive Waste*, No. 9, Brauschweig, October 1985.

(45) Framatome, *Rapport annuel de 1986*, Paris, juin 1987.

(46) Framatome, *Visit to France of a Canadian Delegation Led by Mrs. Barbara Sparrow*, Briefing Notes, Paris, 14 avril 1988.

(47) France, Agence Nationale pour la gestion des Déchets Radioactifs, *ANDRA : A Government Agency for Safe Radioactive Waste Management*, Commissariat à l'Énergie Atomique, Paris, non daté.

(48) France, Commissariat à l'Énergie Atomique, *Les Centrales Nucléaires dans le Monde*, Paris 1987.

(49) Gentner, N.E. et D.P. Morrison, «Detection and Impact on Cancer Causation of Persons Exhibiting Abnormal Susceptibility to Carcinogenic Agents», Toxicology Workshop, Chalk River Nuclear Laboratories, Chalk River (Ontario), 3 novembre 1987.

(50) Gordon, Joshua et al., *1986 Nuclear Power Safety Report*, Public Citizen, Critical Mass Energy Group, Washington, D.C., septembre 1987.

(51) Grisdale, Margaret C., «The Safety Implications of the Legal, Regulatory, and Organisational Framework Within Which Ontario's CANDU Reactors Operate»' *The Safety of Ontario's Nuclear Power Reactors : A Scientific and Technical Review*. Vol. 2 Appendices, Appendix VII, Ontario Nuclear Safety Review, Toronto, 29 février 1988.

(52) Harvie, J.D., *Costs and Benefits of Nuclear Regulation in Canada*, Commission de contrôle de l'énergie atomique, Ottawa, 3 juin 1985.

(53) Howles, Laurie, «Nuclear Station Achievement 1987», *World Nuclear Industry Handbook 1988*, Nuclear Engineering International, Sutton, Angleterre, 1988, p. 19-22.

(17) Canada, Énergie atomique du Canada, Limitée, Exploitation CANDU, *Présentation au Comité permanent de l'énergie, des mines et des ressources*, Sheridan Park, 22 mars 1988b.

(18) Canada, Énergie atomique du Canada, Limitée, Exploitation CANDU, «The Douglas Point Story», *Power Projections* (Special Edition), juin 1984.

(19) Canada, Énergie atomique du Canada, Limitée, Bureau du Québec et Hydro-Québec, Vice-présidence Information, Direction Édition et Production, *Cobalt 60 : Le futur au présent*, Montréal, 1987.

(20) Canada, Énergie atomique du Canada, Limitée, Radiochemical Company, *World List of Industrial Gamma Irradiators*, Kanata (Ontario), mars 1986.

(21) Canada, Énergie atomique du Canada, Limitée, Société de recherche, *Acoustic Borehole Meter*, Laboratoires nucléaires de Chalk River, Chalk River (Ontario), non daté.

(22) Canada, Énergie atomique du Canada, Limitée, Société de recherche, *Eddy Current Probes*, Laboratoires nucléaires de Chalk River, Chalk River (Ontario), mars 1987.

(23) Canada, Énergie atomique du Canada, Limitée, Société de recherche, «AECL Assists U.S. Space Program», *Labstracts*, vol 2, no. 6, juin 1987.

(24) Canada, Énergie atomique du Canada, Limitée, Société de recherche, *TASCC*, Laboratoires nucléaires de Chalk River, Chalk River, Ontario, 1987.

(25) Canada, Énergie, Mines et Ressources, *Revue de l'industrie nucléaire : Problèmes et perspectives 1981-2000*, Ottawa, 1982.

(26) Canada, Énergie, Mines et Ressources, *Aperçu de la politique nucléaire*, rapport ER81-2F, Ottawa, 1981.

(27) Canada, ministère des Affaires extérieures, Visite en France du Comité permanent de l'énergie, des mines et des ressources, Ambassade du Canada, Paris, avril 1988.

(28) Canada, Chambre des communes, Comité permanent de l'énergie, des mines et des ressources, *Le pétrole — Rareté ou sécurité?*, Ottawa, septembre 1987.

(29) Canada, Chambre des communes, Comité permanent de l'environnement et des forêts, Les déchets hautement radioactifs au Canada : La onzième heure a sonné, Ottawa, janvier 1988.

(30) Canada, Science Council, *Food Irradiation: Prospects for Canadian Technology Development Statement*, Ottawa, avril 1987.

(31) Canadian Fusion Fuels Technology Project, *Fusion Energy and Canada's Role*, non daté.

(32) Clegg, L.J. et J.R. Coady, *Radioactive Decay Properties of CANDU Fuel. Volume 1 : The Natural Uranium Fuel Cycle*, AECL-4436/1, Établissement de recherches nucléaires de Whiteshell, Société de recherche de l'énergie atomique du Canada, Pinawa (Manitoba), janvier 1977.

(33) Denault, Paul et Pabrita L. De, «Gentilly 1 Nears "Static State'», *Nuclear Engineering International* (nouveau tirage), août 1985.

(34) «Disallowances by State Regulators for Nuclear Units (1980-1986)», *Nuclear Industry*, mars-avril 1968, p. 84.

(35) Duke Power Company, *1987 Annual Report*, Charlotte, North Carolina, 1988.

Bibliographie choisie

(1) Ahearne, John F., «A Comparison of Nuclear Power Regulation in Canada and the United States», *The Safety of Ontario's Nuclear Power Reactors : A Scientific and Technical Review. Selected Consultants' Reports*, Ontario Nuclear Safety Review, Toronto, 29 février 1988.

(2) Aikin, A.M., J.M. Harrison et F.K. Hare, *La gestion des déchets nucléaires au Canada*, Rapport EP 77-6, Secteur de la politique énergétique, Énergie, Mines et Ressources, Ottawa, 31 août 1977.

(3) American Nuclear Energy Council, *Report to Members and the 100th Congress*, Washington, non daté.

(4) Bothwell, Robert, *Nucleus : The History of Atomic Energy of Canada Limited*, University of Toronto Press, Toronto, 1988.

(5) Boulton, J. (éd.), *Management of Radioactive Fuel Wastes : The Canadian Disposal Program*, AECL-6314, Établissement de recherches nucléaires de Whiteshell, Société de recherche de l'énergie atomique du Canada, Limitée, Pinawa, Manitoba, octobre 1978.

(6) Broad, L.G., *Douglas Point : Summary of Decommissioning to Date*, Énergie atomique du Canada, Limitée, 1er octobre 1986.

(7) Breest, H.-Ch., *Nuclear Energy in the Federal Republic of Germany*, Édition n° 101, Federal Ministry for Environment, Nature Conservation and Nuclear Safety, République fédérale d'Allemagne, mars 1988.

(8) Brooks, G.L. et R.S. Hart, *The CANDU 300 Reactor System*, Exploitation CANDU, Énergie atomique du Canada, Limitée, Mississauga, Ontario, février 1988.

(9) Canada, Commission de contrôle de l'énergie atomique, *Annual Report 1987-88*, Ottawa, 1988.

(10) Canada, Commission de contrôle de l'énergie atomique, *Estimating the Costs of AECB Regulation*, INFO-0023-2, étude effectuée par SECOR Inc. de Montréal, Ottawa, avril 1981.

(11) Canada, Commission de contrôle de l'énergie atomique, *La réglementation des activités nucléaires au Canada*, INFO-0108, Ottawa, 5 décembre 1983.

(12) Canada, Commission de contrôle de l'énergie atomique, *Objectifs, exigences et lignes directrices réglementaires à long terme pour l'évacuation des déchets radioactifs*, document réglementaire R-104, Ottawa, 5 juin 1987a.

(13) Canada, Commission de contrôle de l'énergie atomique, *Les répercussions de l'accident de Tchernobyl sur la sûreté des réacteurs CANDU*, INFO-0234(F), Ottawa, mai 1987b.

(14) Canada, Énergie atomique du Canada, Limitée, *Coup d'oeil sur le nucléaire*, Affaires publiques du bureau central, Ottawa, septembre 1987.

(15) Canada, Énergie atomique du Canada, Limitée, Exploitation CANDU, *CANDU in Canada's Future : A 30-year Vision. A Summary Document*, Mississauga, Ontario, mai 1988a.

(16) Canada, Énergie atomique du Canada, Limitée, Exploitation CANDU, *CANDU 300 Technical Highlights*, Mississauga, Ontario, non daté.

(utilisée dans le traitement industriel, dans le chauffage urbain, etc.), et les réacteurs de propulsion utilisés dans les navires de surface et les sous-marins à propulsion nucléaire.

Réacteur rapide : Réacteur dans lequel la fission nucléaire est provoquée principalement par des neutrons rapides.

Réacteur refroidi au gaz : Réacteur dans lequel un gaz est utilisé comme caloporteur et du graphite comme modérateur. Le réacteur refroidi au gaz, parfois appelé réacteur de type «Magnox», utilise de l'uranium naturel; le «réacteur avancé refroidi au gaz «(AGR) et le «réacteur à haute température refroidi au gaz» (HTGR) utilisent du combustible enrichi.

Réacteur surrégénérateur : Réacteur qui produit de la matière fissile à partir de matière fertile en quantité supérieure à la quantité de matière fissile consommée pour le fonctionnement du réacteur (c.-à-d. dont le rapport de conversion ou de régénération est supérieur à un).

Réacteur thermique : Réacteur dans lequel la fission est produite principalement par des neutrons thermiques ou «lents».

Retraitement du combustible : Traitement du combustible nucléaire après son utilisation dans un réacteur, en vue d'éliminer les produits de fission et de récupérer la matière fissile et la matière fertile.

Uranium enrichi : Uranium dans lequel le pourcentage de l'isotope uranium 235 fissile a été porté au-delà de 0,71 %, proportion dans laquelle on le retrouve dans l'uranium naturel.

Uranium naturel : Uranium dont la composition isotopique est naturelle (99,28 % d'uranium 238 fertile, 0,71 % d'uranium 235 fissile et 0,006 % d'uranium 234).

Gestion des déchets radioactifs : Toutes les activités administratives et opérationnelles qui sont à prendre en compte dans la manutention, le traitement, le conditionnement, le transport, le stockage et l'élimination des déchets radioactifs.

Inventaire de combustible : Quantité totale du combustible nucléaire investi dans un réacteur, un ensemble de réacteurs ou un cycle de combustible tout entier.

Isotopes : Nucléides ayant le même nombre atomique mais des masses différentes (la masse est proportionnelle au nombre total de protons et de neutrons dans le noyau). Par exemple, l'hydrogène, dont le numéro atomique est 1, comprend trois isotopes : l'hydrogène normal ou protium (un proton dans le noyau); le deutérium (un proton et un neutron); et le tritium (un proton et deux neutrons), qui est instable.

Masse critique : Masse minimale de matière fissile de configuration et de composi- tion déterminées, dans des conditions spécifiées, qui peut maintenir une réaction en chaîne critique.

Matière fertile : Isotopes susceptibles d'être transformés, directement ou indirectement, en matière fissile par capture de neutrons (particulièrement l'uranium 238 et le thorium 232).

Matière fissile : Nucléides susceptibles de subir facilement une fission par interaction avec des neutrons lents (exemples : uranium 235, uranium 233, plutonium 239 et plutonium 241).

Modérateur : Matière utilisée pour réduire l'énergie des neutrons (c'est-à-dire pour produire des neutrons «lents» ou thermiques) par diffusion et ralentissement sans capture excessive des neutrons.

Nucléide : Espèce atomique particulière. Le deutérium et le tritium, bien qu'ils soient tous deux des isotopes de l'hydrogène, sont des nucléides différents.

Période : Temps nécessaire pour que la moitié des atomes présents dans une substance radioactive se désintègrent spontanément et que de ce fait la substance voit son activité réduite à la moitié de sa valeur initiale.

Produits de fission : Nucléides produits soit par fission, soit par désintégration radioactive subséquente des nucléides ainsi formés.

Radioactivité : Propriété qu'ont certains nucléides d'émettre spontanément des particules ou un rayonnement gamma à partir de leur noyau, de se scinder spontanément ou d'émettre des rayons X.

Réacteur à eau bouillante : Réacteur dans lequel de l'eau est utilisée comme caloporteur et modérateur, et peut bouillir dans le coeur.

Réacteur à eau lourde : Réacteur utilisant de l'eau lourde comme modérateur. Le caloporteur peut être un gaz, de l'eau ordinaire ou de l'eau lourde (comme dans le réacteur CANDU). Selon le type, le combustible peut être de l'uranium naturel ou de l'uranium enrichi.

Réacteur à eau ordinaire : Réacteur utilisant de l'eau ordinaire (légère) comme caloporteur et modérateur. Le BWR et le PWR sont des exemples de réacteurs à eau ordinaire.

Réacteur (à fission) nucléaire : Dispositif dans lequel une réaction en chaîne auto-entretenue de fission nucléaire peut être maintenue et dirigée. L'expression «réacteur nucléaire» est quelquefois appliquée à un dispositif dans lequel une réaction de fusion nucléaire peut être produite et dirigée (réacteur à fusion).

Réacteur de puissance : Réacteur destiné principalement à produire de l'énergie. Parmi les réacteurs de puissance on compte les réacteurs de production d'électricité, les réacteurs de production de chaleur

CANDU : Famille de réacteurs à fission nucléaire mis au point au Canada, dans lesquels l'uranium naturel est utilisé comme combustible et l'eau lourde comme modérateur et caloporteur.

Combustible nucléaire : Substance contenant un ou plusieurs nucléides fissiles capables d'entretenir une réaction nucléaire en chaîne dans un réacteur. L'expression peut aussi désigner une substance contenant un ou plusieurs nucléides fertiles qui peuvent être transmutés en nucléides fissiles.

Critique : Un réacteur est dit «critique» lorsque le taux de production de neutrons est exactement égal au taux de disparition des neutrons, c'est-à-dire lorsque le facteur de multiplication des neutrons est égal à un. Lorsque le facteur de multiplication dépasse un, le réacteur est «surcritique»; lorsque le facteur est inférieur à un, le réacteur est «sous-critique».

Cycle du combustible : Suite des opérations, par exemple fabrication, utilisation, retraitement, refabrication et réutilisation, auxquelles le combustible nucléaire peut être soumis.

Déchets radioactifs : Matières radioactives indésirables obtenues lors du traitement, de la manipulation ou de l'utilisation des matières radioactives. Ces déchets peuvent être classés selon leur niveau d'activité ou leur période de la façon suivante :

A. Selon la teneur en radionucléides

déchets faiblement radioactifs : déchets qui en raison de leur faible teneur en radionucléides ne nécessitent pas de protection pour leur manipulation normale.

déchets hautement radioactifs : liquides hautement radioactifs séparés pendant le retraitement chimique du combustible irradié; ou combustible irradié du réacteur lorsqu'on ne prévoit pas retraiter le combustible épuisé; ou tout autre déchet d'un niveau de radioactivité comparable.

déchets moyennement radioactifs : déchets ayant un niveau de radioactivité inférieur à celui des déchets hautement radioactifs mais qui nécessitent néanmoins une protection pour leur manipulation.

B. Selon la période

déchets à courte période : déchets dont la radioactivité décroît à un niveau considéré comme insignifiant du point de vue radiologique, dans une période de temps au cours de laquelle les contrôles administratifs peuvent s'exercer. Dans certains pays, les radionucléides ayant un période inférieure à 30 ans sont considérés comme appartenant à cette catégorie.

déchets à longue période : déchets dont la radioactivité ne décroît pas à un niveau acceptable dans une période de temps au cours de laquelle les contrôles administratifs peuvent s'exercer.

Eau lourde : Oxyde de deutérium ou D_2O. Eau dans laquelle l'atome d'hydrogène existe sous forme de l'isotope d'hydrogène appelé deutérium. À l'état pur, l'eau lourde est utilisée comme modérateur et caloporteur dans le réacteur CANDU.

Énergie de fission : Énergie libérée par la fission d'un atome.

Énergie nucléaire : Énergie produite dans une centrale où la vapeur entraînant les turbines est produite à partir de la fission atomique plutôt qu'à partir d'une combustion.

Fission nucléaire : Division d'un noyau lourd en deux parties (rarement plus), habituellement accompagnée de l'émission de neutrons, de rayonnement gamma et de libération d'énergie.

3) Transfert d'équivalents : Échange de quantités égales de puissance ou d'énergie électrique au cours d'une période déterminée.

4) Transfert en vue de la vente : Transfert de puissance ou d'énergie électrique en exécution d'un contrat de vente.

5) Transfert en vue de l'emmagasinage : Transfert d'énergie électrique «accumulée» à l'époque considérée sous la forme d'un volume d'eau retenu dans le réservoir d'un autre service public d'électricité, en prévision de la remise d'une quantité équivalente d'énergie électrique à une date ultérieure.

Transformateur : Dispositif électromagnétique pour élever ou abaisser la tension d'un courant alternatif.

Transmission à courant continu : Transmission d'électricité sous forme de courant continu à la place du courant alternatif habituel. Le courant continu présente certains avantages pour la transmission d'un point à un autre sur de longues distances et pour interconnecter des réseaux qui seraient instables si on essayait de les relier par un courant alternatif. Il existe quatre installations de courant continu haute tension en service au Canada : 1) la liaison sous-marine avec l'Île de Vancouver; 2) la ligne de transmission aérienne au-dessus de la rivière Nelson (Manitoba); 3) la liaison asynchrone au-dessus de la rivière Eel (Nouveau-Brunswick); et 4) la liaison asynchrone de Chateauguay (Québec).

Transport de transit : Transport d'électricité fournie par un service public par l'intermédiaire des circuits d'un autre service public et destinée à une tierce partie ou au réseau de départ.

Très haute tension (T.H.T.) : Toute tension de transmission supérieure aux tensions couramment utilisées. Les services publics d'électricité ont généralement considéré que les T.H.T. étaient égales ou supérieures à 345 kilovolts, bien que de telles tensions soient de plus en plus courantes.

Turbine (hydraulique) : Moteur primaire tournant dans lequel de l'énergie mécanique est produite par la force de l'eau, de la vapeur ou des gaz qui sont dirigés contre un aubage solidaire d'un arbre tournant.

Ultra haute tension : Tension supérieure à 1000 kilovolts environ.

Valeur nominale (figurant sur la plaque signalétique) : Valeur maximale en régime continu d'une génératrice ou d'une autre installation électrique dans les conditions désignées par le fabricant, telle qu'indiquée sur la plaque signalétique apposée sur le dispositif.

Zone de service : Zone dans laquelle un service public d'électricité est tenu ou a le droit de desservir des abonnés.

Terminologie de l'énergie nucléaire

Actinides : Groupe d'éléments de numéro atomique égal ou supérieur à 89 et qui présentent des propriétés chimiques similaires. Ce groupe comprend des éléments naturels, comme le thorium et l'uranium, de même que les éléments «transuraniens», qui sont produits artificiellement, comme le plutonium et l'américium. Parmi leurs isotopes on compte des émetteurs alpha à longue période dont il faut tenir compte dans l'élimination des déchets radioactifs.

Arrêt d'urgence : Action d'arrêter brusquement un réacteur nucléaire pour éviter une situation dangereuse ou en réduire les conséquences.

Caloporteur : Liquide ou gaz que l'on fait circuler à l'intérieur ou autour du coeur d'un réacteur pour évacuer la chaleur.

Réserve tournante : Portion de la puissance de réserve qui est réellement mise en service dans le réseau, et qui, sans produire la puissance maximale, est prête à couvrir automatiquement une charge au moindre avis.

Service public d'électricité : Organisme dont le but principal est de produire, transmettre et/ou distribuer de l'énergie électrique.

Source d'énergie primaire : Source d'énergie primaire à partir de laquelle de l'électricité est produite, par exemple chute d'eau, uranium (par fission nucléaire), charbon, pétrole, gaz naturel, vent, biomasse, rayonnement solaire direct, énergie géothermique et énergie des marées.

Source d'énergie renouvelable : Source d'énergie qui se renouvelle d'elle-même, notamment les diverses manifestations de l'énergie solaire (énergie hydroélectrique, biomasse, énergie éolienne, rayonnement solaire direct, énergie des vagues et courants océaniques), l'énergie des marées et l'énergie géothermique.

Stabilité : Capacité des réseaux d'électricité de demeurer synchronisés.

Supraconducteur : Conducteur électrique qui offre une résistance négligeable au passage de l'électricité.

Surplus d'énergie : Énergie en excès des besoins de son propriétaire, charge et réserve comprises. De l'énergie excédentaire est produite lorsque la puissance totale excède la charge totale; elle est souvent vendue sous la forme d'énergie interruptible.

Synchronisme : État de génératrices de courant alternatif qui sont «en phase», c'est-à-dire synchronisées de façon que leurs ondes de tension atteignent leur maximum et leur minimum exactement au même instant. Cet état est une condition essentielle pour que des génératrices de courant alternatif fonctionnent dans le même réseau.

Tarification au coût marginal : Tarification selon laquelle les prix sont fixés au coût de la dernière unité produite (marginale) plutôt qu'au coût moyen de toute la production.

Tarifs différenciés dans le temps : Tarifs qui varient selon l'heure du jour, le jour de la semaine ou la saison.

Tension : Force électrique, mesurée en volts ou en multiples du volt (par exemple en kilovolts) qui fait circuler un courant dans un circuit. En Amérique du Nord, la tension normalisée à des fins résidentielles est de 115 volts pour la plupart des appareils et de 230 volts pour les gros appareils électroménagers tels que les cuisinières, les sécheuses et les chauffe-eau. Les tensions de distribution dans les secteurs urbains et ruraux varient de 4 à 44 kV environ. Les tensions des lignes de transport les plus courantes sont 115, 132, 230, 345, 500 et 735 kilovolts. Plus la tension est élevée, plus une ligne peut transporter des puissances élevées.

Transfert entre des services publics d'électricité : Transfert de puissance électrique entre au moins deux services publics d'électricité. Le Règlement sur l'Office national de l'énergie (partie VI) définit cinq catégories de transfert entre des services publics d'électricité, à savoir :

1) Transfert en vue d'une correction : Transfert de puissance d'énergie électrique à des fins telles que a) le redressement des comptes de fourniture d'énergie électrique, b) la compensation pour pertes électriques, c) la compensation pour services rendus, d) la livraison de la production faisant l'objet d'un droit ou e) la transmission d'avantages en amont ou en aval.

2) Transfert relatif au transport : Transfert de puissance d'énergie électrique d'un service public d'électricité, en vue de la livraison à une tierce partie ou au service public originaire, par l'intermédiaire des circuits d'un autre service public d'électricité.

Probabilité d'indisponibilité forcée : Probabilité que le service d'un groupe électrogène particulier ou d'un autre élément du réseau soit interrompu en raison d'une panne.

Production indépendante (privée) : Production d'une installation appartenant à des producteurs autres qu'un service public, ou exploitée par ceux-ci. Ces producteurs possèdent habituellement des centrales à seule fin de fournir l'électricité nécessaire au fonctionnement de leurs propres installations industrielles et commerciales. Le terme s'applique aussi aux centrales privées dont le seul but est de vendre de l'électricité à un service public.

Puissance : Taux de livraison d'énergie (par exemple, un service public d'électricité peut vendre une puissance de 50 mégawatts); ou

Quantité maximale d'électricité qu'un élément d'une installation ou un réseau peut transporter ou livrer (par exemple, un groupe électrogène peut avoir une puissance nominale de 50 mégawatts).

Puissance absorbée par les auxiliaires : Puissance électrique absorbée par les installations auxiliaires d'une centrale, plus la puissance dissipée dans les transformateurs de la centrale.

Puissance à court terme : Puissance, et énergie associée, qu'un service public achète à un autre service public dans le but de s'assurer en tout temps un approvisionnement en puissance pendant la période de l'engagement.

Rejet de groupes électrogènes : Débranchement de certains groupes électrogènes dans un réseau électrique pour maintenir un fonctionnement sûr dans le reste du réseau. Cette mesure est quelquefois prise si, à la suite d'une urgence, une grande partie de la charge a été brusquement coupée. La charge est alors insuffisante pour absorber la puissance produite par les génératrices. S'ils ne sont pas débranchés, les groupes fonctionnent avec une vitesse excessive, élevant la fréquence et la tension dans le réseau à des niveaux inacceptables.

Réseau : Réseau de lignes de transport d'électricité et de connexions.

Réseau de distribution : Ensemble des lignes, transformateurs, interrupteurs, etc. utilisés pour distribuer l'électricité aux clients sur de courtes distances à partir du réseau de transmission. La distribution se fait généralement sous des tensions relativement faibles (44 kilovolts et moins).

Réseau d'électricité : Toutes les installations interconnectées d'un service public d'électricité. Un réseau d'électricité comprend les centrales, les transformateurs, les postes de sectionnement, les lignes de transport, les postes, les lignes de distribution et les circuits d'alimentation des abonnés, c'est-à-dire toutes les installations requises pour assurer des services électriques aux abonnés.

Réseau de transport : Lignes, transformateurs, commutateurs, etc., utilisés pour transporter de l'électricité en grande quantité entre des sources d'approvisionnement et d'autres parties principales du réseau. Le transport se fait en général sous des tensions de 115 kilovolts et plus.

Réseau électrique haute tension : Ensemble des installations de production et de transmission de courant haute tension (en général 115 kilovolts et plus).

Réseau interconnecté : Réseau constitué d'au moins deux réseaux électriques individuels reliés entre eux par des lignes d'interconnexion.

Réseau isolé : Réseau d'électricité qui n'est pas interconnecté avec un autre réseau (par exemple, la Commission d'énergie du Nord canadien). Les réseaux isolés ont habituellement une puissance relativement faible.

Indisponibilité : État de toute composante d'un circuit qui ne peut remplir sa fonction prévue à cause d'un événement associé avec cette composante. Une indisponibilité ne cause pas obligatoirement une interruption du service chez des abonnés.

Liaison asynchrone : Interconnexion à courant continu entre deux réseaux à courant alternatif, ainsi appelée car il n'est pas nécessaire que les deux réseaux soient synchrones.

Licence : Licence visant l'exportation de force motrice à l'extérieur du Canada, délivrée aux termes de la partie VI de la *Loi sur l'Office national de l'énergie*, après une audience publique. Toute licence est sujette à l'approbation du Gouverneur en conseil.

Ligne de transport : Ligne utilisée pour transporter de l'électricité sous haute tension. Les lignes de transport peuvent être aériennes, sous-marines ou souterraines. Les lignes de tension inférieures à 115 kilovolts sont habituellement appelées lignes de distribution.

Ligne d'interconnexion synchrone : Toute ligne d'interconnexion en courant alternatif. Tous les groupes électrogènes reliés par une telle ligne doivent être synchronisés.

Mise sous cocon : Conserver le matériel qui est excédentaire pour les besoins courants ou qui a atteint la fin de sa vie normale. Le matériel mis sous cocon ne peut être utilisé immédiatement mais peut, une fois préparé, être réutilisé dans l'avenir.

Moteur primaire : Turbine ou moteur qui entraîne une génératrice.

Période de pointe : Périodes pendant lesquelles des demandes relativement élevées sont satisfaites par un réseau d'électricité, par opposition aux autres périodes.

Pertes : Énergie ou puissance perdue dans des circuits ou du matériel, principalement sous la forme de chaleur, lorsqu'un courant circule dans le circuit.

Planification intégrée : Planification conjointe par différents réseaux d'électricité dans le but de minimiser les coûts totaux. La planification intégrée est une caractéristique d'un véritable consortium d'électricité.

Pluies acides : Terme général s'appliquant à toute forme de précipitation qui a été acidifiée par la présence de polluants atmosphériques, principalement les oxydes de soufre et d'azote.

Pointe d'été : Charge maximale dans un réseau d'électricité pendant l'été, dont la cause est habituellement la climatisation par temps chaud.

Pointe d'hiver : Charge maximale dans un réseau d'électricité pendant la période de six mois allant d'octobre à mars. Au Canada, la pointe d'hiver se produit presque toujours en décembre ou en janvier.

Poste : Station où la tension du réseau d'électricité haute tension est réduite à un niveau se prêtant à la distribution et où l'alimentation en tension réduite commence et peut être coupée ou établie.

Poste de commande : Salle de commande d'où proviennent les instructions pour la commutation des installations électriques, centrales ou lignes, et pour la modification de la quantité d'électricité produite dans les centrales. En général, un tel centre est équipé de télécommandes, d'instruments de télémesure et d'ordinateurs. Des cartes informatisées du réseau indiquent l'état de fonctionnement des groupes électrogènes, des lignes de transmission et des principaux postes. Des appareils de mesure indiquent les charges couvertes par les groupes et les lignes ainsi que les tensions en des points choisis. Ainsi, le surveillant du réseau dispose d'une image complète des principaux éléments du réseau et il peut coordonner les opérations.

Poste de sectionnement : Installation électrique dont la fonction est de connecter ou de déconnecter sélectivement les lignes de transport d'un réseau en antenne.

Énergie d'économie : Énergie vendue par un réseau électrique à un autre afin que soit économisé le coût de production lorsque l'acheteur est capable de couvrir les charges par l'intermédiaire de son propre réseau.

Énergie de remplacement du combustible : Énergie vendue par un service public d'électricité à un autre dans le but de permettre à l'acheteur d'éviter de brûler du combustible dans ses propres installations thermiques. Le prix de l'énergie de remplacement du combustible est généralement égal à un pourcentage du coût de combustible évité par l'acheteur.

Énergie interruptible : Énergie fournie aux termes d'une convention qui permet la réduction et la cessation des livraisons au gré du fournisseur.

Énergie inutilisable : Capacité de production d'énergie dans une centrale qui ne peut être utilisée parce que cette énergie ne peut être transmise correctement de la centrale à la charge. Par exemple, une partie de la capacité de production de la centrale nucléaire Bruce est inutilisable.

Énergie moyenne : Énergie qui serait produite par les centrales hydroélectriques dans un système fluvial dans des conditions de débit moyen.

Énergie ou technologie de substitution : Source d'énergie ou technologie qui n'est pas encore largement utilisée, par opposition aux sources d'énergie et aux technologies «classiques». Le terme s'applique généralement aux sources d'énergie renouvelables et à de petites installations décentralisées. Exemple : énergie photovoltaïque, chauffage solaire, énergie éolienne et production d'électricité à partir de déchets.

Entente d'interconnexion : Entente passée entre deux services publics d'électricité pour gérer l'exploitation des interconnexions entre leurs réseaux respectifs. En général, une telle entente définit différentes classes de transferts d'électricité entre les services publics et précise les tarifs qui seront applicables entre les deux services publics.

Entretien programmé : Entretien du matériel effectué conformément à un calendrier préétabli.

Facteur de charge : Pour toute installation, rapport entre la charge moyenne pendant une certaine période et la puissance nominale de l'installation. Le facteur d'utilisation est généralement exprimé en pourcentage.

Gestion de la demande : Mesures prises par un service public d'électricité ou un autre organisme pour modifier la consommation d'électricité des clients (quantité consommée ou heures de consommation). Ces mesures peuvent être divisées en trois groupes : croissance de la charge, décalage de la charge et réduction de la charge.

Groupe de pointe : Groupe électrogène destiné à fonctionner de façon intermittente pour couvrir les charges de pointe.

Groupe électrogène : Ensemble qui comprend la génératrice, le moteur primaire qui entraîne la génératrice et tous les éléments connexes qui doivent fonctionner ensemble pour produire de l'électricité. Un groupe électrogène peut généralement fonctionner indépendamment des autres groupes dans une station qui en comprend plusieurs.

Haute tension : Toute tension supérieure à 750 volts.

Hertz : Unité de fréquence des courants alternatifs, autrefois exprimée en cycles par seconde. En Amérique du Nord, la fréquence du courant de secteur a été normalisée à 60 hertz.

Coûts sociaux : Coûts ou dommages, tangibles ou intangibles, qui découlent d'un projet. Les coûts sociaux se distinguent des coûts privés en ce sens qu'ils comprennent tous les coûts d'un projet qui sont à la charge de tous les citoyens plutôt que les coûts qui sont à la seule charge des promoteurs du projet.

Débit moyen d'un cours d'eau : Moyenne arithmétique de tous les débits observés dans un cours d'eau pendant une période donnée, en général un an.

Décalage de la charge : Déplacement de la demande d'électricité d'une période à une autre, habituellement d'une période de pointe à une période de faible charge.

Délestage : Interruption de l'alimentation en électricité d'un secteur ou d'un groupe d'abonnés pour maintenir le fonctionnement sûr et ininterrompu du reste d'un réseau d'électricité. Cette mesure est parfois prise en cas d'urgence lorsque la charge totale du réseau dépasse la capacité de production disponible pour la couvrir.

Demande : Quantité d'électricité que les clients veulent acheter. Le terme «demande» est souvent utilisé comme synonyme de «puissance», qui est la quantité d'énergie électrique fournie par unité de temps.

Demande de pointe : Charge maximale consommée par un abonné, par un groupe d'abonnés ou par l'ensemble du réseau au cours d'une période déterminée, par exemple un an.

Diagramme de charge : Évolution de l'utilisation ou de la production d'électricité lorsque la demande est représentée en fonction du temps.

Disjoncteur : Interrupteur servant à ouvrir ou à fermer un circuit électrique pendant le fonctionnement normal du système ou lors d'une panne.

Distribution de la charge : Courbe qui, pour une période déterminée (par exemple un jour, un mois ou un an), indique le pourcentage de temps pendant lequel la demande a dépassé différentes valeurs ou différents pourcentages de la valeur maximale.

Diversité saisonnière : Variation de la charge dont les maximums sont répartis au cours des différentes saisons de l'année. Par exemple, les pointes annuelles de la plupart des réseaux d'électricité canadiens se produisent en hiver, tandis que celles d'un grand nombre de réseaux américains se produisent en été à cause des besoins de climatisation. Les réseaux qui présentent de telles différences peuvent réaliser des économies d'échelle en concluant des échanges d'énergie sur une base saisonnière.

Économie de partage : Formule très répandue de tarification de l'énergie, notamment de l'énergie d'économie vendue par un service public à un autre, selon laquelle l'économie totale résultant d'une vente est partagée également entre l'acheteur et le vendeur.

Économie stratégique : Améliorations de rendement que n'entreprendraient pas les abonnés seulement pour les économies qu'ils pourraient réaliser. Pour promouvoir les initiatives d'économie stratégique, les services publics d'électricité ou les gouvernements doivent fournir une aide financière, créer d'autres incitatifs ou éliminer les barrières.

Électrotechnologie : Technologie qui fait appel à l'électricité, en particulier les nouvelles technologies utilisées pour remplacer d'autres sources d'énergie. Exemple : les pompes à chaleur électriques utilisées pour sécher le bois dans des fours, à la place de l'air chauffé par combustion sur place.

Emprise (ou tracé) : Bande de terrain sur laquelle une ligne de transport d'électricité est située et sur laquelle la compagnie d'électricité a acquis le droit légal d'effectuer des travaux de construction et d'entretien, de limiter la croissance de la végétation, et parfois de limiter les travaux de construction par des tiers. La largeur de l'emprise varie en fonction de la tension de la ligne.

Centrale thermique : Centrale dont les génératrices sont entraînées par des gaz ou de la vapeur produits par des combustibles (tels que le charbon, le pétrole, le gaz, le bois ou des déchets) en combustion ou par une réaction nucléaire.

Charge (hydraulique) : Différence de hauteur entre le niveau d'eau immédiatement en amont d'une centrale hydroélectrique et le niveau d'eau immédiatement en aval. La puissance de la centrale est proportionnelle à la charge hydraulique.

Charge de base : Charge minimale constante pendant une période donnée.

Circuit : Tout conducteur ou ensemble de conducteurs servant à transporter l'électricité.

Circuit commun : Ensemble de conducteurs électriques servant de connexions communes entre deux ou plusieurs circuits. Un circuit commun peut être constitué de barres rigides («barres omnibus») ou de câbles.

Coefficient ou facteur de charge : Rapport de la charge moyenne pendant une période désignée à la charge maximale ou de pointe pendant la même période, habituellement exprimée en pourcentage de la charge de pointe. Le coefficient de charge annuel pour l'ensemble du réseau d'Ontario Hydro est d'environ 68 %.

Cogénération : Production conjointe d'électricité et de chaleur utile (en général sous forme de vapeur).

Consommation spécifique de chaleur : Mesure du rendement thermique d'une centrale, généralement exprimée en British thermal units par kilowattheure net. Pour la calculer, il faut diviser l'enthalpie totale (Btu) du combustible brûlé par la production résultante nette d'électricité en kilowattheures. En unités métriques, la consommation spécifique de chaleur est exprimée en kilojoules par kilowattheure.

Consortium d'électricité : Groupement d'au moins deux réseaux d'électricité interconnectés, conçus et exploités pour couvrir de la manière la plus fiable et la plus économique possible leurs charges combinées.

Convertisseur : Installation dont la fonction est de convertir un courant continu en un courant alternatif ou une fréquence de courant alternatif en une autre.

Courant : Circulation d'électricité dans un conducteur. Le courant est mesuré en ampères.

Courant alternatif : Courant électrique qui circule alternativement dans un sens puis dans le sens inverse. En Amérique du Nord, la norme est de 60 cycles complets par seconde; on dit alors que le courant a une fréquence de 60 hertz. On utilise presque toujours le courant alternatif dans les réseaux électriques car il peut être transmis et distribué beaucoup plus économiquement que le courant continu.

Courant continu : Courant qui circule toujours dans le même sens (par opposition au courant alternatif). Le courant fourni par une batterie est un courant continu.

Coût de production marginal croissant : Coût de production d'une unité additionnelle d'énergie électrique au-delà d'une quantité de base préétablie.

Coût évité : Coût que devrait assumer un service public d'électricité pour accroître la puissance installée si ce service devait produire lui-même l'électricité au lieu de l'acheter d'un producteur indépendant.

Coût marginal : Coût de production d'une unité additionnelle d'électricité. Lorsque l'unité additionnelle peut être fournie simplement en augmentant la production de la centrale existante, ce coût est habituellement qualifié de «coût marginal à court terme» ou «coût croissant»; lorsqu'une nouvelle centrale doit fournir la production additionnelle, ce coût est habituellement qualifié de «coût marginal à long terme».

ANNEXE E

Terminologie

Les définitions données dans la présente section et dans la section suivante sont extraites, avec des modifications mineures, du rapport de l'ONE intitulé *Électricité : Compendium de termes*, bulletin d'information n° 8, mai 1985; du rapport d'Ontario Hydro intitulé *Meeting Future Energy Needs : Draft Demand/Supply Planning Strategy*, rapport 666 SP, décembre 1987; et du rapport de la Conférence mondiale de l'énergie intitulé *Energy Terminology*, 2e édition, Pergamon Press, 1986.

Terminologie des réseaux d'énergie électrique

Accumulation ou emmagasinage : Eau retenue dans un réservoir. L'eau accumulée sert à compenser les variations naturelles du débit d'un cours d'eau de façon que la production d'une centrale hydroélectrique fluctue le moins possible pendant de telles variations naturelles.

Accumulation par pompage : Aménagement selon lequel de l'eau est pompée d'un réservoir d'aval dans un réservoir d'amont, en dehors des périodes de pointe. Pendant les périodes de pointe, l'eau est libérée dans le réservoir d'aval à travers des turbines hydroélectriques, produisant ainsi de l'électricité. Les turbines sont habituellement réversibles de sorte qu'elles peuvent aussi servir de pompes dans le système.

Anhydride sulfureux : Gaz asphyxiant, inodore et lourd, dont la formule chimique est SO_2. On en retrouve dans les gaz de carneau des chambres de combustion, notamment celles des centrales thermiques. En présence de lumière, il se combine à la vapeur d'eau dans l'atmosphère pour produire de l'acide sulfurique; avec d'autres acides, il mène au phénomène des précipitations acides.

Avantages sociaux : Avantages, tangibles ou intangibles, découlant d'un projet. Les avantages sociaux se distinguent des avantages privés en ce sens qu'ils comprennent tous les avantages d'un projet, peu importe s'ils profitent aux promoteurs du projet.

Capacité de production (ou productibilité) : Charge maximale qu'une centrale ou une installation est capable de couvrir dans des conditions spécifiées.

Centrale : Centrale comprenant un ou plusieurs groupes électrogènes pour la production d'électricité. Les principaux types de centrales sont les centrales hydroélectriques, les centrales nucléaires et les centrales thermiques (au charbon, à l'huile ou au gaz naturel). Dans certaines régions du monde, comme dans la région des Geysers en Californie, les centrales géothermiques commencent à couvrir une part importante de la puissance installée.

Centrale au fil de l'eau : Centrale hydroélectrique qui n'a pratiquement pas de réservoir et qui doit donc exploiter l'écoulement naturel du cours d'eau. La puissance de la centrale peut donc être sujette à des variations considérables.

Centrale de base : Centrale normalement utilisée pour couvrir la charge de base ou une partie de la charge de base d'un réseau et qui, partant, fonctionne à puissance maximale lorsque cette puissance est disponible. Les centrales de base sont en général de grandes installations dont les coûts d'exploitation sont bas.

Centrale hydroélectrique : Centrale dont les moteurs primaires sont des turbines hydrauliques.

KSU	Kärnkraftsäkerhet och Utbildning AB (Centre de formation et de sûreté nucléaires de la Suède)
KWU	Kraftwerk Union (Allemagne de l'Ouest)
LMFBR	réacteur surrégénérateur à neutrons rapides refroidi par métal liquide
LNCR	Laboratoires nucléaires de Chalk River
LWGR	réacteur à graphite à eau ordinaire
LWR	réacteur à eau ordinaire
MWe ou MW	mégawatts (électriques)
MWt	mégawatts (thermiques)
NEI	Nuclear Engineering International (États-Unis)
NIAC	Pool canadien d'assurance des risques atomiques
NPD	Centrale nucléaire de démonstration
NRC	Nuclear Regulatory Commission (États-Unis)
NRU et NRX	réacteurs de recherche (Canada)
OCDE	Organisation de coopération et de développement économiques
ONÉ	Office nationale de l'énergie
PHWR	réacteur à eau lourde sous pression
PTB	Physikalisch-Technische Bundensanstalt (Agence physique-technique, Allemagne de l'Ouest)
PWR	réacteur à eau ordinaire sous pression
R et D	recherche et développement
R, D et D	recherche, développement et démonstration
RBMK	reactor Bolche Molchnastie Kipiache (URSS)
REP	réacteur à eau sous pression
RFA	République fédérale d'Allemagne
RWE	Rheinisch-Westfälisches Elektrizitätswerk (Allemagne de l'Ouest)
SFR	dépôt final des déchets de réacteurs (Suède)
SKB	Svensk Kärnbränslehantering AB (Société suédoise de gestion du combustible et des déchets nucléaires)
SKI	Statens kärnkraftinspektion (Corps d'inspection de l'énergie nucléaire de la Suède)
SKN	Statens kärnbränslenämnd (Commission nationale suédoise du combustible nucléaire épuisé)
SKR	devise suédoise (couronne)
SR	Société radiochimique
SRSC	système de refroidissement de secours du coeur
SSI	Statens stralskyddsintitut (Institut national suédois de radioprotection)
THTR	réacteur à haute température au thorium
USCEA	U.S. Council for Energy Awareness
ZEEP	Zero Energy Experimental Pile

ANNEXE D

Abréviations et sigles utilisés dans le rapport

ACÉ	Association canadienne de l'électricité
AEC	Atomic Energy Commission (États-Unis)
AGR	réacteur avancé refroidi au gaz
AIÉA	Agence internationale de l'énergie atomique (Autriche)
ANC	Association nucléaire canadienne
ANDRA	Agence Nationale pour la gestion des Déchets Radioactifs
ANEC	American Nuclear Energy Council
Bq	Becquerel (unité de mesure de la radioactivité)
BWR	réacteur à eau bouillante
CANDU	CANada-Deutérium-Uranium
CANDU-BLW	réacteur CANDU à eau ordinaire bouillante
CANDU-OCR	réacteur CANDU refroidi par matière organique
CANDU-PHWR	réacteur CANDU à eau lourde sous pression
CCÉA	Commission de contrôle de l'énergie atomique
CÉA	Commissariat à l'Énergie Atomique (France)
CÉÉNB	Commission d'énergie électrique du Nouveau-Brunswick
CGÉ	Compagnie générale électrique du Canada
CERN	Organisation européenne pour la recherche nucléaire
CLAB	installation centrale de stockage provisoire du combustible nucléaire épuisé (Suède)
DOE	Department of Energy (États-Unis)
ÉACL	Énergie atomique du Canada Limitée
ÉdF	Électricité de France (France)
ÉMR	Énergie, Mines et Ressources Canada
EPA	Environmental Protection Agency (États-Unis)
EURATOM	Communauté européenne de l'énergie atomique
FBR	réacteur surrégénérateur à neutrons rapides
GCR	réacteur refroidi au gaz
GGCR	réacteur à l'uranium naturel, modéré au graphite et refroidi au gaz
GW	gigawatt
HTR	réacteur à haute température
HWP	usine d'eau lourde
HWR	réacteur à eau lourde
INPO	Institute of Nuclear Power Operations (États-Unis)

SENSYS, Nepean

Philip Campbell, directeur général

Groupe de recherche d'intérêt public des États-Unis

Cathleen Welch, coordonnatrice de la politique énergétique

Ken Bossong, Projet sur la masse critique

Sous-comité de l'énergie et de l'électricité de la Chambre des représentants

Sue Sheridan, conseillère

Tom S. Runge, conseiller

Pat Davis, conseiller, Commission de réglementation nucléaire

Conseil de l'énergie nucléaire des États-Unis

Edward M. Davis, président

John T. Conway, président du conseil et vice-président administratif, Affaires générales, Consolidated Edison Company of New York, Inc.

Andrea Dravo, vice-présidente, Planification stratégique

Kevin Billings, vice-président, Relations gouvernementales

Diane Holmes, directrice, Développement

Duke Power Company

K.P. Lau, spécialiste des affaires du Congrès, ministère de l'Ingénierie

Déplacement du Comité dans la région d'Ottawa, le 26 mai 1988

AECL Radiochemical Company, Kanata

Paul O'Neil, président

David Drummond, directeur, Contrôle de la qualité des isotopes

John Worswick, directeur, Opérations liées au cobalt

AECL Medical Products Division, Kanata

Frank H. Warland, vice-président

Peter E. Habgood, directeur général, Fabrication

Robert L. Wolff, directeur général, Services, Technologie, Administration et Ressources humaines

Steve R. Lee, directeur commercial

Betsy O'Brien, Division des prévisions et de l'analyse des données, Gestion de l'information en matière d'énergie

Dan Nikodem, Bureau des combustibles de remplacement et du nucléaire, Gestion de l'information en matière d'énergie

Wanda M. Klimkiewicz, adjointe, Programme international, Bureau des affaires internationales et des situations d'urgence énergétique

Comité du Sénat sur l'énergie et les ressources naturelles

Benjamin S. Cooper, personnel d'encadrement

Mary Louise Wagner, personnel d'encadrement

Marilyn Meigs, cadre, Bureau du sénateur James A. McClure

Commission de la réglementation nucléaire

Harold Denton, directeur, Affaires publiques et gouvernementales

Stuart A. Treby. conseiller juridique adjoint en matière de réglementation du cycle combustible

Joseph F. Sento, conseiller juridique adjoint suppléant en matière d'audiences

Hans B. Schechter, spécialiste principal des relations internationales

Service de recherche du Congrès

Warren H. Donnelly, spécialiste principal

Robert L. Ciciak, chef, Section de la technologie avancée, Division de la recherche sur la politique scientifique

Carl E. Behrens, chef, Section des minéraux et des combustibles, Division des ressources naturelles et de l'énergie

Francis T. Miko, spécialiste en relations internationales, Division de la Défense nationale et des Affaires étrangères

Mark Holt, analyste de la politique énergétique

Conseil américain d'information en matière d'énergie

Harold B. Finger, président-directeur général

Bill Harris, vic-président principal

Paul Turner, vice-président, Communications et publications industrielles

John R. Siegel, vice-président, Programmes techniques

Carl A. Goldstein, vice-président, Relations avec le public et les médias

Commissariat à l'Énergie atomique, Paris

Pierre Cachera, directeur, Technologie et Équipement

Pierre Hammer, adjoint au directeur de la Technologie

Philippe Raimbault, Liaison — Relations internationales

Framatome, Paris

Pierre-Yves Gatineau, président, Relations internationales

Association France-Canada, Paris

Sénateur Adolphe Chauvin, président

Agence nationale pour la gestion des déchets radioactifs, Paris

Armand Faussat, adjoint au directeur

Institut national des sciences et techniques nucléaires, Saclay

Yves Chelet, directeur

Georges Le Guelte, adjoint au directeur

Déplacement du Comité à Washington (D.C.), du 1 au 4 mai 1988

Ambassade du Canada

Leonard H. Legault, sous-chef de mission et ministre (Économie)

T. D'Arcy McGee, conseiller (Commerce)

Jonathan Fried, premier secrétaire

Ross Glasgow, premier secrétaire

Ministère de l'Énergie

Theodore J. Garrish, sous-secrétaire

Del Bunch, sous-secrétaire adjoint principal, Énergie nucléaire

Richard H. Williamson, sous-secrétaire adjoint, Affaires extérieures

Jerome Saltzman, sous-directeur, Bureau du développement et de la localisation des installations, Bureau de la gestion civile des déchets radioactifs

Mary Ann Novak, adjointe spéciale au sous-secrétaire, Énergie nucléaire

Lennart Devell, sous-chef, Analyse des systèmes et de la sécurité, Division nucléaire

Per Linder, directeur de projet, Division nucléaire

Société de gestion des déchets et des combustibles nucléaires de la Suède, Stockholm

Sten Bjurström, président

Régie d'État de l'énergie de Suède, Östhammar

Arthur Monsen, directeur, Département des services

République Fédérale d'Allemagne

Ambassade du Canada, Bonn

Son Excellence W.T. Delworth

Maureen Lofthouse, conseillère, Science et Technologie

Richard Têtu, conseiller, Politique

Christian Luckner, Science et Technologie

Dennis Baker, consul général du Canada (Düsseldorf)

Gouvernement de la République fédérale d'Allemagne, Bonn

Albert Probst, secrétaire d'État parlementaire, ministère fédéral de la Recherche et de la Technologie

Martin Grüener, secrétaire d'État parlementaire, ministère fédéral de l'Environnement, de la Conservation de la nature et de la Sécurité nucléaire

Rheinisch-Westfälisches Elektrizitätswerk AG, Essen

Klaus P. Messer, directeur

France

Ambassade du Canada, Paris

Alain Dudoit, conseiller politique

Robert Hage, conseiller, Affaires politiques

Jean-Pierre Juneau, ministre-conseiller, Affaires politiques

Ian MacLean, conseiller économique

RESOLUTE Development Corp., Kincardine

Sam MacGregor, président

Déplacements du Comité en Suède, en République Fédérale d'Allemagne et en France, du 8 au 16 avril 1988

Suède

Ambassade du Canada, Stockholm

Son Excellence Dennis B. Browne

Gregory J. Kozicz, troisième secrétaire et vice-consul

Ministère de l'Environnement et de L'Énergie, Stockholm

M. Rolf Annerberg, sous-secrétaire d'État

Lars Ekecrants, expert

Centre de sécurité et de formation nucléaire, Nyköping

Rolf I. Odin, ingénieur principal et directeur de projets

Institut national de la protection contre les radiations, Stockholm

Gunnar Johansson, agent de protection contre les radiations

Régie nationale du combustible nucléaire épuisé, Stockholm

Olof Söderberg, directeur

Nils Rydell, ingénieur en chef

Margaretha Stalfors, directrice financière

Bureau d'inspection de l'énergie nucléaire de la Suède, Stockholm

Sören Norrby, directeur, Division des déchets nucléaires

Studsvik Energiteknik AB, Nyköping

Walter Hübner, vice-président, Recherche et développement, Division de la technologie énergétique

Claes Harfors, vice-président, Service des centrales, Division nucléaire

Eric Hellstrand, vice-président, Analyse des systèmes et de la sécurité, Division nucléaire

Harvey R. Lee. directeur — Manutention des combustibles nucléaires, Systèmes d'énergie et Services

Invar Manufacturing Ltd, Batawa

Brian Riden, vice-président et directeur général

Maurice Mainville, directeur général des ventes

James A. Steenburg, directeur du contrôle des matériaux

Opérations CANDU, Énergie atomique du Canada, Limitée, Mississauga

Don S. Lawson, président

H.M. VanAlstyne, vice-président, Technique

Dennis R. Shiflett, vice-président, Unité fonctionnelle des services techniques

L. John Ingolsfrud, vice-président, Unité fonctionnelle de Ontario Hydro

David N. Harrington, adjoint exécutif du président

Masoneilan/Dresser Canada, Inc., Mississauga

Brian E. Minns, vice-président et directeur général

Ray Briggs, directeur des ventes et de la commercialisation

Babcock & Wilcox Canada, Cambridge

Paul Koenderman, président

James Smith, directeur de la commercialisation des produits nucléaires

Malcolm Cox, directeur des projets

Dennis Dueck, directeur du génie

Bruce Nuclear Power Development, Ontario Hydro, Tiverton

Terry D. Squire, Relations internes

Brian Wood, directeur des opérations

Darrell Davidson, directeur

Les Broad, directeur de la centrale, Centrale de Douglas Point

Cameron D. Campbell, analyste, Relations gouvernementales, Relations internes (Toronto)

ANNEXE C

Déplacements du Comité

Le Comité permanent de l'énergie, des mines et des ressources a effectué trois déplacements en Ontario et deux à l'étranger afin d'approfondir ses connaissances en matière d'énergie. Voici la liste des organismes et des personnes que le Comité a consultés au cours de ses voyages.

Déplacement du Comité aux laboratoires nucléaires de Chalk River, le 1er mars 1988

Laboratoires nucléaires de Chalk River, Chalk River

Peter J. Harvey, directeur général, Laboratoires nucléaires de Chalk River

Ralph E. Green, vice-président, Développement des réacteurs

Howard K. Rae, vice-président, Utilisation des rayonnements et isotopes

J.C. Douglas Milton, vice-président, Physique et Sciences de la Santé

Donald H. Charlesworth, directeur, Division de la technologie de la gestion des déchets

Bernard DeAbreu, directeur, Direction générale de l'exploitation des réacteurs

Rudy M. Lepp, directeur Division des éléments et de l'instrumentation

Gerald F. Lynch, directeur général, Unité fonctionnelle des systèmes d'énergie locaux

Norman E. Gentner, Direction générale de la radiobiologie

William R. Taylor, spécialiste technique, Direction générale de la conception des systèmes mécaniques

Lorna E. Evans, directrice, Affaires publiques

Déplacement du Comité dans le sud et l'est de l'Ontario, du 20 au 23 mars 1988

Compagnie générale électrique du Canada Limitée, Peterborough

Paul Schofield, vice-président, Systèmes d'énergie et Services

Sil Dragan, directeur — Commercialisation, Manutention des combustibles nucléaires, Systèmes d'énergie et Services

Dean A. Wasson, directeur — Produits nucléaires, Système d'énergie et Services

Dave Irwin, directeur — Manutention des combustibles nucléaires, Système d'énergie et Services

Témoins	Date	Fascicule
De la Commission d'énergie électrique du Nouveau-Brunswick :	04/03/88	40
Terry Thompson, directeur des affaires publiques;		
A.R. Mackenzie, directeur d'usine.		
De Marbec Resource Consulting :	10/03/88	41
Brian Kelly, président.		
De Torrie, Smith and Associates :		
Ralph Torrie, président.		
De Trans-Alta :	10/05/88	42
Walter Saponja, premier vice-président, Génération;		
Ed Barry, vice-président, Recherches.		
De l'Ontario Nuclear Safety Review :	14/06/88	43
M. Kenneth Hare, président.		

Témoins	Date	Fascicule
De l'Enquête énergétique :	19/11/87	33
Norman Rubin, directeur, Recherche nucléaire.		
De l'Association nucléaire canadienne :	01/12/87	34
Noel O'Brien, président du conseil;		
Michael Harrison, président;		
Ian Wilson, vice-président;		
Rita Dionne-Marsolais, vice-présidente, Information;		
Nick Ediger, directeur et ancien président du conseil.		
De l'Association canadienne de l'électricité :	15/12/87	37
Wallace Read, président		
Hans Konow, directeur, Affaires publiques.		
De Ontario Hydro :	16/12/87	38
Lorne McConnell, vice-président, Programme du réseau;		
Mitch Rothman, économiste en chef et directeur, Études économiques et prévisions;		
Ken Snelson, directeur, Planification des ressources du réseau de grand transport;		
Ted Bazeley, directeur, Approvisionnement en combustibles fossiles;		
Richard Furness, agent des relations gouvernementales.		
De la firme Passmore Associates International :	02/03/88	39
Jeff Passmore, président;		
David Argue, associé principal.		

ANNEXE B
Liste des témoins

Témoins	Date	Fascicule
Du ministère de l'Énergie des Mines et des Ressources :	03/11/87	29
Arthur Kroeger, sous-ministre;		
Robert W. Morrison, directeur général, Direction de l'uranium et de l'énergie nucléaire;		
Ted Thexton, conseiller, Nucléaire.		
De l'Énergie atomique du Canada Limitée :	04/11/87	30
James Donnely, président;		
Stan Hatcher, président, Société de recherche;		
Ronald Veilleux, secrétaire corporatif et vice-président; des relations de l'entreprise;		
Michel Therrien, vice-président exécutif.		
De l'Office national de l'énergie :	18/11/87	31
Roland Priddle, président;		
Mark Segal, directeur, Direction de l'économie;		
Alex Karas, directeur, Direction de l'électricité.		
De la Commission de contrôle de l'énergie atomique :	18/11/87	32
René J.-A. Lévesque, président;		
Zigmund Domaratzki, directeur général, Direction générale de la réglementation des réacteurs;		
David Smythe, directeur général, Direction générale de la réglementation des matières nucléaires et des radioéléments;		
John Beare, directeur, Direction des études normatives;		
R.W. Blackburn, directeur, Direction de la planification et de l'administration.		

Déclaration du député de Yorkton—Melville

Les Néo-démocrates reconnaissent et respectent la réelle inquiétude que soulève dans le grand public la participation active du Canada à l'âge nucléaire. C'est pourquoi ils ont accepté de prendre part à l'examen économique de l'énergie nucléaire qui ne fut pas, comme les Conservateurs l'avaient promis, une enquête parlementaire sur tous les aspects du cycle du combustible nucléaire. Nous avions espéré que le Comité se pencherait au moins sur les aspects économiques de la question en toute objectivité. Malheureusement, l'analyse du Comité est si simpliste et si aveuglément pro-nucléaire que les Néo-démocrates se doivent de la rejeter.

Le Comité n'a pas su déterminer les coûts réels du nucléaire ni ne s'est attaché à considérer sérieusement le potentiel économique et énergétique des économies d'énergie et des sources d'énergie de remplacement, tel l'hydrogène. Le rapport du Comité est un tel ramassis de données choisies, d'hypothèses subjectives et de pures spéculations qu'on est presque tenté de conclure qu'il a été rédigé par l'industrie nucléaire elle-même, et non par un Comité impartial de la Chambre des communes.

ANNEXE A

DEUX OPINIONS DIVERGENTES

Déclaration du député de Cape Breton—The Sydneys

Je pense, comme le Comité, que l'énergie nucléaire est une source d'énergie future nécessaire et acceptable du point de vue de l'environnement, bien que ses lacunes m'apparaissent plus importantes que ne le laisse entendre le rapport, et je fais miennes les 14 recommandations formulées. Contrairement au Comité, toutefois, je n'accepte pas que certains importants aspects du développement du nucléaire soient confiés au secteur privé.

Le Comité est favorable à la privatisation de la Société radiochimique et de la Division des produits médicaux à la condition que l'ÉACL retienne un intérêt minoritaire dans les nouvelles sociétés et que le contrôle de celles-ci ne passe pas à l'étranger. Je m'oppose à la privatisation de ces secteurs de l'ÉACL car j'estime qu'il est contraire aux intérêts du pays que la commercialisation de toute une gamme de substances radioactives se fasse par le secteur privé, et parce que l'ÉACL perdrait une importante source de revenu. La fabrication et la vente de radioisotopes à des fins médicales, d'irradiation des aliments et des eaux usées et industrielles seraient mieux contrôlées par le secteur public. Je ne m'oppose cependant pas, de façon générale, à la privatisation des secteurs commerciaux de l'ÉACL, dont bon nombre travaillent au développement d'utilisations technologiques non nucléaires.

Pour des raisons semblables, je désapprouve le déploiement commercial du SLOWPOKE, même s'il s'agit d'un réacteur thermique comparativement sûr. L'idée que le Canada soit parsemé de tels réacteurs de faible puissance exploités par des intérêts privés à des fins de chauffage urbain ou de production de chaleur industrielle me tracasse.

Vu le risque que présentent les substances radioactives pour la santé, je préfère que le gouvernement garde le contrôle des utilisations de l'énergie atomique.

d'intérêt pour les programmes de formation en nucléaire observé chez les nouveaux étudiants reflète l'opinion peu favorable au nucléaire d'une partie importante de la population et la crainte des faibles possibilités d'avancement.

Compte tenu de l'âge moyen du personnel technique spécialisé dans le domaine nucléaire, des 30 à 40 ans (peut-être même plus) de soutien opérationnel requis pour les réacteurs de puissance et de la pénurie de personnel nouveau, on devra accorder une attention particulière au maintien d'un bassin adéquat de compétences techniques dans les années 1990 et au-delà.

Suite au ralentissement général des activités dans l'industrie, certaines sociétés ont réduit ou cessé leurs activités dans le domaine nucléaire. La DSMA-Atcon, une société d'experts-conseils du secteur privé, auparavant active dans le domaine nucléaire, a apparemment cessé ses activités canadiennes en 1986-1987. Le Groupe d'Analyse Nucléaire, qui exerçait ses activités à l'École Polytechnique de Montréal, n'offre plus de services de soutien à l'Hydro-Québec. La CAE n'a pas été choisie à la suite de l'offre présentée par son Service du simulateur de centrale nucléaire en réponse à un appel d'offres récent; elle a perdu une partie de son personnel spécialisé en nucléaire, et elle remettrait apparemment en question ses activités reliées au simulateur de réacteur. Un grand nombre des travailleurs spécialisés qui ont quitté ces organisations sont une perte permanente pour l'industrie du nucléaire. Cette érosion de la main-d'oeuvre dans la base industrielle qui soutient le programme de l'énergie nucléaire est aussi inquiétante.

Pour supporter l'industrie nucléaire dans les années à venir, il faudrait élaborer un cadre institutionnel solide. Le gouvernement fédéral devrait énoncer une position claire concernant le rôle qu'il entend faire jouer à l'énergie nucléaire dans le développement énergétique futur au Canada et indiquer dans quelle mesure il appuie l'option nucléaire. Le public a besoin de mieux connaître la position du gouvernement fédéral en matière de gestion des déchets radioactifs ainsi que de sécurité et de responsabilité dans le domaine de l'énergie nucléaire. L'étude ontarienne à paraître concernant les aspects économiques de la production d'énergie électrique d'origine nucléaire par l'Ontario Hydro viendra clarifier cet aspect de la situation.

Une autre avenue est l'"usine de kaons" proposée. Les responsables du TRIUMF, l'installation nationale canadienne d'étude des mésons, située à Vancouver, ont proposé récemment la construction, au coût de 400 millions de dollars, d'un accélérateur qui produirait des faisceaux de particules plus énergiques et plus intenses destinés à une vaste gamme d'études de pointe en science fondamentale et en science appliquée. Un grand nombre des compétences requises pour la construction de cette usine de kaons sont les mêmes que les compétences requises dans l'industrie du nucléaire, et elles touchent notamment la robotique, la télémanipulation, la surveillance des radiations et la protection contre les radiations.

Ce projet offre la possibilité de maintenir cette base de compétences par l'expansion des activités d'un grand nombre de participants de l'industrie. L'ÉACL, par son expérience de participation aux travaux effectués sur le TRIUMF et ses compétences éprouvées dans ces secteurs de technologie, semble un candidat pour des travaux importants de conception et de génie.

Suite à la proposition des responsables du TRIUMF, on attend maintenant que le gouvernement fédéral prenne une décision relative au financement.

Au sein même de l'ÉACL, un certain nombre de services commerciaux tentent de trouver des applications commerciales aux retombées technologiques du nucléaire. Au Service commercial SENSYS, situé à Nepean, que le Comité a visité, on met présentement au point un dispositif de surveillance de l'usure des moteurs destiné aux marchés militaires et industriels. La Morton-Thiokol des États-Unis a accordé à l'ÉACL un contrat d'études techniques visant à améliorer les joints toriques d'étanchéité de moteur du lanceur de la navette, dont la défaillance a provoqué la destruction de Challenger. Une société satellite de Chalk River a été établie pour commercialiser les détecteurs de rayonnement basés sur la méthode de détection à bulles mise au point par l'ÉACL. Ce sont là des exemples de mesures importantes visant à élargir et diversifier le champ d'activités de l'ÉACL.

Une tendance inquiétante est la pénurie de personnel scientifique et technique compétent qui commence à se faire sentir dans tous les secteurs de l'industrie nucléaire, en dépit du ralentissement des activités. De nombreuses organisations canadiennes, des secteurs public et privé, signalent qu'elles éprouvent des difficultés à trouver du personnel expérimenté pour combler les postes vacants. Bien que cette pénurie soit pour l'instant limitée aux postes des niveaux intermédiaire et supérieur, la baisse marquée du nombre d'étudiants inscrits aux programmes de formation en nucléaire des universités et des collèges pose un grave problème de main-d'oeuvre à long terme.

Les facteurs qui contribuent à la pénurie à court terme sont notamment l'attrition normale et la perte de personnel au niveau intermédiaire attribuable aux faibles possibilités d'avancement dans un domaine de plus en plus restreint. Le manque

QUEL EST L'AVENIR DE L'INDUSTRIE NUCLÉAIRE CANADIENNE?

L'Ontario Hydro devra accroître la capacité de production de son réseau dans les années 1990, mais il n'est pas assuré que le prochain accroissement sera basé sur l'énergie nucléaire. L'Hydro-Québec envisage l'agrandissement de son complexe hydro-électrique de la Baie James, et il est peu probable qu'elle envisage l'addition d'installations nucléaires avant une date éloignée dans le XXIe siècle. La Commission d'énergie électrique du Nouveau-Brunswick pourrait être un acheteur pour le CANDU 300, mais elle est prudente sur le plan de l'engagement financier. Une entente de partage des risques avec le gouvernement fédéral semble nécessaire pour que ce projet puisse aller de l'avant. Néanmoins, la vente d'un CANDU 300 est essentielle pour l'effort de commercialisation de l'ÉACL, et le gouvernement fédéral devrait étudier attentivement la possibilité d'un accord avec la CÉÉNB.

Il est évident que les ventes de réacteurs seules ne permettront pas à l'ÉACL de traverser sans aide financière la période creuse qui s'annonce. Afin de réduire la nécessité de recours à l'aide fédérale, l'ÉACL doit considérer d'autres avenues commerciales.

L'une de ces avenues est le Programme canadien d'acquisition de sous-marins. Dans son récent Livre blanc, le ministre de la Défense annonçait l'intention du gouvernement de faire l'acquisisition d'une flotte de 10 à 12 sous-marins à propulsion nucléaire. On a par la suite demandé l'aide de l'ÉACL pour l'évaluation des vendeurs potentiels du réacteur de propulsion nucléaire. Celle-ci a répondu en établissant un Service de propulsion marine à Ottawa. Un groupe de travail composé de personnel supérieur de la Société de recherche et des Opérations CANDU de l'ÉACL a récemment joué un rôle consultatif auprès du programme des sous-marins.

Comme l'ÉACL représente le principal bassin de connaissances et de compétences en matière de technologie nucléaire, il est à prévoir que ce rôle consultatif s'élargira à mesure que les exigences du programme se préciseront. En raison des inquiétudes exprimées par les fournisseurs étrangers potentiels de réacteurs au sujet de la confidentialité du transfert de technologie, il semble probable que la participation de l'ÉACL en tant que société de la Couronne serait préférée à celle des sociétés de nucléaire du secteur privé. Il a été suggéré que l'ÉACL agisse en tant que principal contractant pour tous les éléments nucléaires du programme des sous-marins.

Étant donné les exigences du programme des sous-marins en matière de contenu canadien, l'acquisition créerait un nombre appréciable d'emplois tant à l'ÉACL que dans l'industrie nucléaire du secteur privé.

toutes deux l'énergie nucléaire comme un élément essentiel et toujours plus important de leur système de production d'énergie électrique.

Le programme nucléaire des États-Unis rencontre des difficultés sur plusieurs fronts. La complexité de la réglementation, les retards dus à cette réglementation, les poursuites engagées par divers groupes, la prolifération des types de réacteurs, l'insuffisance des ressources et de la formation du personnel assurées par certaines compagnies durant la réalisation de leurs programmes nucléaires, contribuent à élever considérablement les coûts. Le Comité est encore incertain quant à la façon de résoudre ces divers problèmes. Le gouvernement des États-Unis a pris des mesures pour faire progresser le programme de gestion des déchets radioactifs, ce qui peut rassurer un peu le public, mais jusqu'à présent, il ne semble pas que le gouvernement et l'industrie nucléaire aient découvert la façon de surmonter le malaise général de l'industrie.

E. Conclusion

D'après les données économiques qu'il a examinées, le Comité conclut que l'énergie nucléaire est moins coûteuse que l'énergie produite par des combustibles fossiles dans les installations de l'Ontario Hydro et de la *New Brunswick Electric Power Commission*. Ceci ne veut pas dire que les coûts du nucléaire sont toujours plus bas. Le remplacement des tubes des installations 1 et 2 a fait passer temporairement le coût énergétique unitaire de la centrale Pickering A au-dessus de celui d'une centrale au charbon de l'Ontario Hydro, de capacité équivalente. Le remplacement des tubes dans les installations 3 et 4 aura des conséquences moins sérieuses, maintenant que l'Hydro a établi un fonds d'amortissement pour couvrir ces dépenses. La NBEPC fait remarquer qu'à Point Lepreau, le coût énergétique unitaire, qui est de 5,5 cents le kilowatt-heure, a surpassé le coût de la production d'électricité à partir de pétrole à Coleson Cove en 1986. Toutefois, Point Lepreau était une source bien moins coûteuse d'électricité avant l'effondrement des prix du pétrole, et l'électricité d'origine nucléaire redeviendra concurrentielle lorsque le prix du pétrole aura remonté. Un autre élément de supériorité de Point Lepreau est la performance exceptionnelle de ce réacteur pendant ses cinq premières années de fonctionnement.

Plus inquiétante est la tendance de l'énergie nucléaire à perdre progressivement une partie de sa rentabilité économique par rapport au charbon, comme l'indiquent les données de l'Ontario Hydro. Même si l'on ne tient pas compte de l'impact du remplacement des tubes à Pickering, l'avantage économique du nucléaire est amoindri. La raison principale en est l'escalade du coût en capital des centrales Pickering B, Bruce B et Darlington au-delà des valeurs facilement explicables par les forts taux d'inflation de cette période. Dans de tels cas, il faut effectuer des analyses des coûts plus récentes et plus détaillées pour suivre en détail cette évolution et comprendre ses conséquences pour l'avenir.

Sur la scène internationale, le Comité perçoit une situation ambiguë. En France et en Suède, l'électricité d'origine nucléaire présente un net avantage par rapport aux autres méthodes de production d'électricité à grande échelle, malgré la décision prise par la Suède de progressivement réduire la capacité de production de ses centrales nucléaires. En Allemagne de l'Ouest, l'électricité d'origine nucléaire est nettement moins coûteuse que celle produite à partir du charbon extrait du sous-sol de ce même pays, et l'on prévoit que cette tendance continuera à s'accentuer. En Allemagne, étant donné le bas prix actuel du charbon thermique, le coût de l'électricité produite à partir de charbon rejoint presque celui de l'électricité d'origine nucléaire, mais les compagnies allemandes de services publics devront installer des épurateurs dans leurs centrales thermiques, et cet énorme investissement fera monter énormément le coût de la production d'électricité à partir du charbon. La France et l'Allemagne considèrent

à 1988/1989, les fonds affectés par le fédéral à la Commission de contrôle de l'Énergie atomique ont totalisé 187,8 millions $. Le financement par le fédéral du programme de fusion nucléaire, principalement du projet conjoint Tokamak de Varennes au Québec, s'élève à environ 33 millions $. Par conséquent, au total, le gouvernement fédéral a investi près de 7 milliards de dollars dans le développement de l'énergie nucléaire en 40 ans. Les coûts de l'eau lourde ont joué un rôle prépondérant dans le développement de l'énergie nucléaire au Canada, puisqu'ils représentent presque le quart de toute l'aide financière du gouvernement fédéral.

Pour ce qui est des coûts de la réglementation, le fardeau du financement de la CCÉA, l'organisme national de réglementation, ne pèse pas sur les titulaires de permis. Par comparaison, aux États-Unis, le Congrès a exigé de la *Nuclear Regulatory Commission* qu'elle perçoive des utilisateurs des frais pour couvrir 45 % de son budget. Pour 1988, le budget de la NRC est de 392,8 millions $US. Les dépenses totales de réglementation de la CCÉA ont été de 42 millions de dollars entre 1946 et 1979. Ses dépenses annuelles se chiffrent maintenant à environ 24,4 millions de dollars, sans compter les dépenses consacrées à la recherche par la CCÉA qui s'élèvent à 79,2 millions $ pendant cette période.

Enfin, toute la question de la responsabilité nucléaire fait l'objet d'un débat continu entre les critiques du nucléaire et l'industrie. À l'heure actuelle, la *Loi sur la responsabilité nucléaire* exige des exploitants qu'ils souscrivent une assurance civile de 75 millions de dollars pour chacune de leurs installations. Cette assurance se compose de deux volets.

a) La CCÉA exige une assurance de base, que l'exploitant contracte auprès d'un assureur privé approuvé. Au Canada, il s'agit en l'occurrence du consortium appelé Pool canadien d'assurance des risques atomiques (NIAC).

b) L'exploitant doit souscrire une assurance supplémentaire, jusqu'à concurrence de 75 millions pour certaines installations. Cette assurance peut prendre la forme d'une entente de réassurance passée avec le gouvernement fédéral, pourvu que cette entente soit approuvée par le Conseil du trésor.

En 1987, les primes d'assurance des centrales Pickering A et B ainsi que Bruce A et B de l'Ontario Hydro ont été de 1,667 million de dollars. En 1986, les primes représentaient environ 0,1 % du coût de l'électricité produite. Si l'entière responsabilité devait être à la charge de l'industrie nucléaire, les frais d'assurance modifieraient l'économique de l'électronucléaire. Certains adversaires du nucléaire prétendent même que les coûts de l'option nucléaire deviendraient alors prohibitifs au Canada, même si la NRC américaine a proposé de transférer aux services publics nucléaires américains l'entière responsabilité qu'elle assumait. Le Comité ne croit pas qu'une plus grande assurance-responsabilité publique au Canada représentera un fardeau excessif pour l'industrie nucléaire.

L'Ontario Hydro prévoit retarder le déclassement et attendre 30 ans entre la fermeture d'une installation et son démontage. Pour estimer le coût futur de l'élimination du combustible irradié, l'Ontario Hydro pose comme hypothèse qu'une installation commerciale d'élimination des déchets acceptera du combustible irradié à partir de l'an 2010. À la fin de 1987, l'Ontario Hydro avait accumulé 306 millions de dollars en coÛts d'élimination de carburant irradié. Le rapport de l'Ontario Hydro indique la série de suppositions faites pour calculer le coût de retubage, de déclassement et d'élimination du combustible.

4. L'aide gouvernementale

Ceux qui critiquent le développement du nucléaire au Canada mentionnent fréquemment l'aide massive accordée par le gouvernement à la recherche et au développement dans le domaine nucléaire et disent qu'aucune autre industrie n'a joui d'une aide comparable. Jusqu'à la fin de l'année financière 1978-1979, le gouvernement fédéral avait investi au total environ 3,4 milliards de dollars courants dans le développement et l'utilisation de l'énergie nucléaire au Canada, selon une étude préparée en 1980 par le ministère des Finances (Canada, ÉMR, 1981, p. 301-330).

Cette étude présentait un résumé de l'aide accordée par le gouvernement fédéral dans quatre grandes catégories. Sur les 3,4 milliards de dollars investis depuis la Deuxième Guerre mondiale, 56 % ont été consacrés au développement de l'énergie nucléaire, 22 % à la production d'eau lourde, 22 % au financement des ventes d'énergie nucléaire et 2 % à l'appui de l'industrie de l'uranium.

Dans cette étude, les dépenses ont été en outre subdivisées selon les rubriques suivantes : 1) recherche et développement — 2137,1 millions de dollars; 2) réacteurs prototypes (Douglas Point et Gentilly 1) — 157,5 millions de dollars; 3) réacteurs commerciaux — 385,5 millions de dollars; 4) ventes de réacteurs à l'exportation — 305,4 millions de dollars; 5) usines d'eau lourde — 540,2 millions de dollars; 6) réglementation et assurances — 41,8 millions de dollars; 7) Eldorado nucléaire Ltée — 64,7 millions de dollars; 8) Uranium Canada Ltée — 42,7 millions de dollars; et 9) flux financiers divers — 16,0 millions de dollars. Certaines de ces dépenses étaient des emprunts à rembourser, par exemple, lors de la mise en service d'un réacteur exporté ou lors de la conclusion de ventes d'eau lourde.

Récemment, le Comité a obtenu des renseignements qui indiquent que le gouvernement fédéral a investi 3,3 milliards de dollars en plus depuis l'année financière 1978/1979. L'ÉACL a reçu la majeure partie de cette subvention — 3 085,6 millions $ pendant l'année financière 1987/1988 pour financer la R et D nucléaire, le programme fédéral de production d'eau lourde, et le déclassement et la protection des réacteurs prototypes. Sur ce total, 816,9 millions $ correspondent à la radiation des prêts aux usines d'eau lourde et des intérêts qu'elles ont à payer. De l'année financière 1979/1980

Dans une étude réalisée en 1986 par l'Agence de l'OCDE pour l'énergie nucléaire, à laquelle le Canada a fourni des informations, on évaluait le coût de déclassement d'installations nucléaires (OCDE, AÉN, 1986a). Le déclassement y était divisé en trois étapes. La première étape du déclassement consiste à bloquer et à sceller les systèmes mécaniques tout en conservant la première barrière de contamination utilisée pendant l'exploitation. Certains systèmes de manipulation du carburant peuvent être maintenus opérationnels pour d'éventuels travaux de décontamination. L'accès à l'enceinte de confinement est contrôlé et l'usine est surveillée en permanence. La deuxième étape du déclassement consiste à enlever les pièces du réacteur facilement démontables et à mettre en place une barrière de contamination à long terme. Si l'enceinte de confinement a cessé de jouer un rôle de protection radiologique, elle peut être éliminée. Les parties non radioactives de l'usine peuvent être recyclées. La surveillance est moins serrée. La troisième étape du déclassement consiste à éliminer tous les équipements et les ouvrages contaminés. À moins d'être alors réutilisé, le site ne fait plus l'objet de restrictions et il n'est plus nécessaire de le surveiller.

En se fondant sur ces étapes de déclassement et en convertissant les données nationales reçues en dollars US de 1984, l'AÉN a calculé le coût du déclassement d'un réacteur de 1300 MWe de taille standard, incluant un fond de prévoyance de 25 %. Pour un PHWR de 1300 MWe de type CANDU, le déclassement (troisième étape) immédiat atteindrait le coût actualisé de 145 millions de dollars (1984). Si la stratégie utilisée était de commencer par un déclassement de première étape, suivi d'un stockage de 30 ans et d'un déclassement de troisième étape, le coût actualisé atteindrait 117 millions de dollars US (1984). En appliquant un taux d'escompte de 5 % à l'année de fermeture, les coûts passent à 129 millions de dollars US (1984) pour le déclassement immédiat et à 29 millions de dollars pour le déclassement différé (OCDE, AÉN, 1986a, p. 9). En supposant 1) une vie utile du réacteur de 20, 25 ou 30 ans; 2) une stratégie de déclassement immédiat ou différé; et 3) des taux d'escompte de 0 %, 5 % ou 10 %, le coût de déclassement d'un PHWR de 1300 MWe par unité d'électricité produite pendant la vie du réacteur a été, dans tous les cas, inférieur à un millième de dollar US (1984) par kilowatt-heure. Des taux d'escompte plus élevés et une plus longue vie utile du réacteur ont pour effet de faire baisser le coût unitaire calculé (OCDE, AÉN, 1986a, p. 62-63).

L'Ontario Hydro prévoit dans sa comptabilité le déclassement des réacteurs et le coût d'élimination des combustibles dans la catégorie «coûts d'enlèvement des biens fixes et de l'élimination du combustible irradié» (Ontario Hydro, 1988a, p. 43). Le coût d'enlèvement des biens fixes comprend le coût de déclassement des centrales nucléaires et des usines de production d'eau lourde après leur mise hors service, ainsi que le coût du remplacement des chambres de combustible. À la fin de l'année 1987, l'Ontario Hydro avait accumulé 311 millions de dollars de coûts d'enlèvement (162 millions pour le déclassement et 149 millions pour le remplacement des chambres de combustible).

au cours du reste de la durée de l'entente (soit d'ici à 2003). Par conséquent, seulement un tiers environ du coût du retubage sera perçu auprès des clients tarifés de l'Ontario Hydro; le reste sera, en fait, déduit des recettes qu'auraient autrement enregistrées l'ÉACL et la province de l'Ontario de l'exploitation des unités 1 et 2.

Au 31 décembre 1987, le montant du déficit s'élevait à 205 millions de dollars (Ontario Hydro, 1988a, p. 38), l'ÉACL et la province se partageant le remboursement de cette dette à parts à peu près égales. Selon l'entente modifiée, l'Ontario Hydro doit commencer la récupération de cette somme lorsque les deux unités seront remises en service.

Pour être juste, il faut cependant souligner que l'expérience acquise a permis d'établir des mesures préventives pour les installations futures et de réaliser des techniques complexes et efficaces de détection et de correction des problèmes de tubes de force.

3. Gestion des déchets nucléaires et déclassement des centrales

La question de la gestion des déchets nucléaires soulève la controverse au Canada, comme dans la plupart des pays dotés de programmes électronucléaires. Le coût estime de l'élimination de ces déchets ne sera pas vraiment établi tant que le gouvernement et l'industrie nucléaire n'auront pas adopté de politique définitive d'élimination de leurs déchets. Bien qu'il soit convaincu que la gestion des déchets nucléaires se fait avec sérieux et dans un total esprit de sécurité au Canada, le Comité admet que la question, et les coûts potentiellement élevés qui en découlent, ne se pose même pas dans le cas des centrales non nucléaires.

Le coût du déclassement des installations nucléaires est un autre facteur dont il faut tenir compte dans les calculs. La durée de vie utile d'un réacteur CANDU n'a pas encore été déterminée avec précision mais il faudra engager des sommes supplémentaires lorsqu'il sera déclassé. Bien que plusieurs installations soient en cours de déclassement au Canada, la plus récente étant le réacteur NPD, aucune grande station comptant plusieurs réacteurs n'est encore parvenue à la fin de son cycle opérationnel. Cela ne surviendra que dans vingt ou trente ans. Il a donc fallu estimer les coûts de déclassement de même que les fonds actuellement mis de côté à cette fin.

Il est plus facile, par contre, de moderniser des centrales alimentées en combustibles fossiles, en y intégrant de nouveaux équipements ou de nouvelles technologies, et aussi plus probable qu'on utilise une partie de leur puissance pour couvrir des pointes plus tard durant leur vie. On peut ainsi reporter à plus tard les importants investissements nécessaires à leur remplacement, ou même songer à les moderniser, ce qui est plus facile que de financer la construction d'une nouvelle centrale.

dollars, par 705 tonnes produites). En 1988, le rythme de production ayant été bien plus faible, le coût est estimé à 563 $ le kilogramme (en divisant le coût de production de 243,1 millions de dollars, prévu pour 1988, par 432 tonnes d'eau lourde). Pour 1989, l'Hydro prévoit une production plus élevée et un coût projeté de 351 $ le kilogramme. Il s'agit ici du coût unitaire de production, non de la valeur marchande — le montant que reçoit l'Hydro pour des ventes extérieures n'est pas toujours lié aux coûts de production.] La société estime, dans sa comptabilité interne, que le coût de l'approvisionnement initial en eau lourde des quatre nouveaux réacteurs de Darlington s'élèvera à 1 539 millions $ (avec les frais de transport et de stockage) sur un coût total en capital estimé maintenant à 11 171 millions $ (Communication personnelle : Cameron Campbell, Relations gouvernementales, Ontario Hydro, 8 août 1988). Si l'on postule qu'il faut disposer d'un inventaire initial en eau lourde de 0,8 tonne par mégawatt de puissance installée à Darlington, le coût unitaire de l'eau lourde est alors approximativement de 545 $ le kilogramme (sans compter les frais de transport et de stockage).

2. Problèmes des tubes de force des CANDU

La détérioration des tubes de force des réacteurs de la centrale Pickering A est un bon exemple de ce qui peut aller de travers, même dans les meilleures conditions de planification et de développement. L'Ontario Hydro estimait que les coûts directs des matériaux, de la main-d'oeuvre et de l'équipement nécessaires à l'enlèvement et au remplacement des tubes de force, y compris la remise en service des unités 1 et 2 de Pickering, atteignaient 402 millions de dollars en novembre 1987. À cela il faut ajouter le coût de l'énergie de remplacement, soit environ de 200 000 à 250 000 dollars par jour pour chacun des réacteurs. Par conséquent, le coût de l'énergie de remplacement a plus que doublé les répercussions financières directes du retubage.

Le retubage des unités 1 et 2 ne relève pas uniquement de l'Ontario Hydro. Même si ces deux unités appartiennent à cette société, elle a conclu avec la province de l'Ontario et l'ÉACL une entente couvrant leur construction et leur exploitation. Conformément à cette entente de récupération des investissements nucléaires, l'Ontario Hydro a versé annuellement aux deux autres parties des sommes s'élevant aux deux tiers environ des avantages financiers découlant de l'exploitation des deux réacteurs (fondés sur l'avantage opérationnel net lié à l'électricité produite par les unités 1 et 2 de Pickering comparativement aux unités 1 et 2 de Lambton, alimentées au charbon). D'autre part, l'entente prévoyait que les coûts du retubage et de l'énergie de remplacement seraient assumés à parts égales par l'ÉACL et la province. Depuis la fin de 1983, la valeur de la récupération des investissements a été négative et l'est demeurée durant le retubage. L'Ontario Hydro ne s'est pas adressée aux deux autres parties pour l'acquittement de cette dette; selon une clause modifiée de l'entente de récupération des investissements, Ontario Hydro récupérera ce «déficit» accumulé, incluant les intérêts,

Tableau 22 : Coûts des CANDU de l'Ontario Hydro comparés aux coûts estimés des PWR pour 1985

		PWR	
	CANDU	**Facteur de charge élevé**	**Facteur de charge moyen**
Puissance de la centrale (MWe nets)	4 x 809	4 x 809	4 x 809
Facteur d'utilisation	78 %	68 %	61 %
Coût énergétique unitaire, intérêt et amortissement			
Capital sec	10,44	11,98	13,35
Mise en service	0,42	0,48	0,54
Combustible	0,14	0,69	0,77
Eau lourde	2,75	–	–
Coût énergétique unitaire total, intérêt et amortissement	**13,75**	**13,15**	**14,66**
Coût énergétique unitaire, exploitation, maintenance et administration	4,18	4,79	5,34
Coût énergétique unitaire, entretien du combustible	4,65	8,90	8,90
Coût énergétique unitaire, entretien de l'eau lourde	0,37	–	–
Coût énergétique unitaire total	**22,95**	**26,84**	**28,90**

Source : Ontario Hydro, *Economics of CANDU–PHW – 1985*, NGD–10, Toronto, août 1986, p. 37.

Il est clair, d'après le tableau 22, que l'eau lourde est une composante importante des coûts du programme canadien. Dans ces calculs, les frais initiaux d'approvisionnement en eau lourde et de maintien des réserves d'eau lourde représentent 13,6 % du CEUT du CANDU, qui s'élève à 22,95. D'après l'Ontario Hydro, le coût de la production d'eau lourde à Bruce dépend du rythme de production. Pour 1987, l'Ontario Hydro indique que le coût de la production d'eau lourde s'élève à 364 $ le kilogramme (en divisant le coût de production total en 1987, soit 256,6 millions de

Il ressort manifestement du tableau 21 que le coût en capital des trois centrales les plus modernes est considérablement supérieur à celui des centrales initiales Pickering A et Bruce A, même en tenant compte de l'inflation.

Parmi les réacteurs de puissance, le CANDU est cher. Son coût en capital est plus élevé qu'un réacteur LWR de capacité comparable. À ce coût s'ajoutent les frais non récurrents de la charge d'eau lourde de CANDU. [Le coût estimé de l'inventaire initial d'eau lourde destinée aux quatre nouveaux réacteurs de Darlington est de 1 539 millions $, ce qui représente presque 14 % du coût total en capital prévu pour la centrale.] Bien que les frais d'exploitation du CANDU soient beaucoup moindres que ceux d'un LWR, les coûts initiaux demeurent un important élément de la décision de tout service public quant au choix du type de réacteur qui sera installé.

Le tableau 22 résume des données de l'Ontario Hydro comparant une centrale à quatre réacteurs CANDU, (en se basant sur les coûts de la centrale Bruce A) à une centrale à quatre réacteurs PWR comparable. Tous les coûts énergétiques unitaires sont exprimés en dollars de 1985 par mégawatt-heure d'équivalent électrique. Les coûts du déclassement, de l'évacuation du combustible épuisé et du retubage ne sont pas inclus dans le tableau 22. Les réacteurs CANDU sont censés fonctionner avec un facteur de capacité nette moyen de 78 %; dans le cas des PWR, l'analyse est faite avec un facteur «élevé» de 68 %, puis avec un facteur «moyen» de 61 %.

Le coût énergétique unitaire total du CANDU est inférieur à celui du PWR, mais des hypothèses de calcul peuvent être remises en question. Le facteur de capacité nette présumé du PWR est en moyenne de 61 %, le chiffre ayant été établi d'après des données d'exploitation internationales de 1985. [Le facteur de charge sur la durée de vie, pondéré en fonction de la capacité mondiale des PWR à la mi-1987 était en moyenne de 62,7 %.] Par ailleurs, les facteurs de charge annuels moyens obtenus dans plusieurs pays industrialisés exploitant au moins quatre PWR ont été de beaucoup supérieurs au facteur «élevé» de 68 % employé au tableau 22. La Suisse, qui exploite trois PWR et deux BWR, a réalisé un facteur de charge cumulatif de 79,7 % au 30 juin 1987. Le facteur de charge était de 79,3 % pour la Finlande (deux PWR et deux BWR) et de 78,0 % pour la Belgique, qui exploite huit PWR (NEI, 1988, p. 13 et 19). Ainsi, quelques pays ont amélioré de façon notable le rendement des PWR et des BWR.

La décision d'exclure les coûts de l'enlèvement des tubes de force, fondée sur le fait que «ces exclusions ont un effet négligeable sur les coûts relatifs de différents types de centrales nucléaires dans le cadre d'un programme important» (Ontario Hydro, 1986a, p. 36), semble aussi devoir être remise en question. Bien que l'Ontario Hydro tienne compte maintenant des coûts futurs du déclassement, de l'évacuation du combustible et du remplacement des tubes de force, les auteurs de l'étude constatent que ces coûts «sont entachés d'une trop grande incertitude pour être indicatifs dans les comparaisons entre différents types de centrale» (Ontario Hydro, 1986a, p. 36).

Étant donné que la majeure partie des coûts des centrales nucléaires sont encourus dès le début (en raison de l'importance des coûts de construction par rapport aux frais d'exploitation et au coût du combustible), les services publics ont de toute façon à faire face à des frais de financement élevés et tout retard du programme de construction a des conséquences beaucoup plus coûteuses que dans le cas d'une centrale thermique dont les coûts de construction (ou en capital) constituent une proportion relativement moindre des coûts totaux au cours de la vie d'une centrale. Enfin, il faut généralement plus de temps pour raccorder au réseau une centrale nucléaire qu'une centrale thermique de capacité équivalente. Cela signifie que non seulement les frais de financement d'une centrale au charbon sont moins élevés, mais aussi que le charbon permet l'adoption de stratégies de planification plus souples et plus pertinentes. L'évolution des coûts en capital des réacteurs CANDU, exprimés en dollars courants, par unité de puissance nette installée de l'Ontario Hydro (incluant l'équivalent électrique de l'énergie-vapeur utile produite à la centrale Bruce-A) est présentée au tableau 21.

Tableau 21 : Évolution des coûts des centrales nucléaires de l'Ontario Hydro, en dollars courants par kilowatt de puissance nette installée

Centrale	Coût spécifique ($/kWe)	Années de mise en service
Coût réel		
Pickering A	362,4	1971-1973
Bruce A	606,0	1977-1979
Coût estimé		
Pickering B	1871,1	1983-1986
Bruce B	1821,8	1984-1987
Darlington	3095,3	1988-1992

Source : Ontario Hydro, *Economics of CANDU–PWH – 1985*, NGD–10, Toronto, août 1986, p. 27.

ont été attribués aux mesures d'hygiène et de sécurité et aux mesures environnementales liées à la protection contre les rayonnements. De ce total, on estime que 196,9 millions (6,4 %) représentent les coûts qu'aurait encourus un utilisateur prudent mais non soumis à une réglementation; on a estimé à 112,6 millions $ (3,6 %) le coût marginal de la réglementation.

Pour évaluer les coûts des mesures de sécurité et de réglementation dans un réacteur en activité, on a choisi l'exemple de la centrale Bruce A pendant l'année d'exploitation 1980. On a estimé à 30,7 millions $, soit à 8,9 % du coût total de la production d'électricité par la centrale Bruce A pendant l'année, le coût total des dépenses consacrées aux mesures d'hygiène et de sécurité et aux mesures environnementales liées à la protection contre les rayonnements. On a estimé à 15,55 millions $ (4,5 %) les coûts qu'aurait encourus un utilisateur non soumis à la réglementation; le coût marginal de la réglementation représente donc 15,15 millions $ (4,4 %).

La CCÉA est parvenue à la conclusion que les coûts de la réglementation des réacteurs nucléaires au Canada ne représentaient qu'un pourcentage relativement faible du coût total de la production d'électricité. Toutefois, la Commission a signalé que ces résultats n'étaient qu'approximatifs parce qu'ils étaient fondés sur l'étude de deux centrales spécifiques et qu'il était difficile de répartir correctement les dépenses entre l'utilisateur prudent et le coût marginal de la réglementation. Quoi qu'il en soit, «l'existence d'un organisme compétent de réglementation semble être une condition préalable pour que le public accepte le programme CANDU de production d'énergie nucléaire» (Harvie, 1985, p. 2).

D. Les arguments économiques contre le nucléaire

1. Profil des dépenses

Le risque et l'incertitude sont deux éléments indésirables, et par suite coûteux, de tout projet d'investissement. Abstraction faite des aspects se rattachant à la sûreté, tout investissement dans une centrale nucléaire par rapport à une centrale au charbon comparable est perçu par de nombreux services publics comme extrêmement risqué. Cette perception est renforcée par le témoignage de la CÉÉNB devant le Comité concernant une deuxième unité à Pointe-Lepreau. Bien que les services publics étatiques du Canada ne soient pas dans la même position que les services privés des États-Unis (où les coûts en capital sont sensibles au moindre retard attribuable à des blocages du processus réglementaire dus aux pressions du public), les frais de financement, c'est-à-dire le produit du capital emprunté par le taux d'intérêt, sont tout aussi sensibles aux retards.

comparaison détaillée de la gestion du combustible épuisé, du déclassement et d'autres coûts spécifiques au nucléaire.

Tableau 20 : Avantage en termes de coûts des centrales nucléaires sur les centrales au charbon d'Ontario Hydro en 1985

Centrale	% d'avantage en termes de coûts (1985) (nucléaire sur le charbon)	
Pickering A vs. Lambton (a)	17 %	(1983 : 29 %)
Pickering B vs. centrale de base au charbon (b)	21 %	
Bruce A vs. Nanticoke	27 %	(1983 : 40 %)
Bruce B vs. centrale de base au charbon (b)	21 %	

a) N'englobe pas les unités 1 et 2 de Pickering qui étaient hors service pour retubage.

b) Suppose que des centrales comparables alimentées au charbon seraient équipées de laveurs à pulvérisation.

Source : Calculé à partir des données contenues dans : Ontario Hydro, *Economics of CANDU–PHW – 1985*, NGD–10, Toronto, août 1986.

Au Canada, on ne considère pas le coût de la réglementation nucléaire comme un problème important. Dans un rapport publié en 1985, la CCÉA a évalué les coûts de la réglementation nucléaire principalement à partir des résultats d'une étude faite à contrat par la SECOR Inc. (Canada, CCÉA, 1981). Dans son étude, la SECOR a identifié les coûts associés aux mesures d'hygiène et de sécurité et aux mesures environnementales liées à la protection contre les rayonnements dans chaque portion du cycle d'utilisation du combustible nucléaire. On a ensuite subdivisé ces coûts en deux composantes : 1) les coûts qui auraient été encourus par un utilisateur prudent en l'absence de toute réglementation; et 2) les coûts uniquement encourus pour que soient respectées les exigences en matière de réglementation, et que l'on appelle «coût marginal de la réglementation».

Pour évaluer les incidences de la réglementation sur le coût en capital de la production d'énergie nucléaire, on a examiné la centrale Pickering B. Sur un coût en capital global de 3 097 millions $ pour cette centrale, 309,5 millions $, soit 10 % du total,

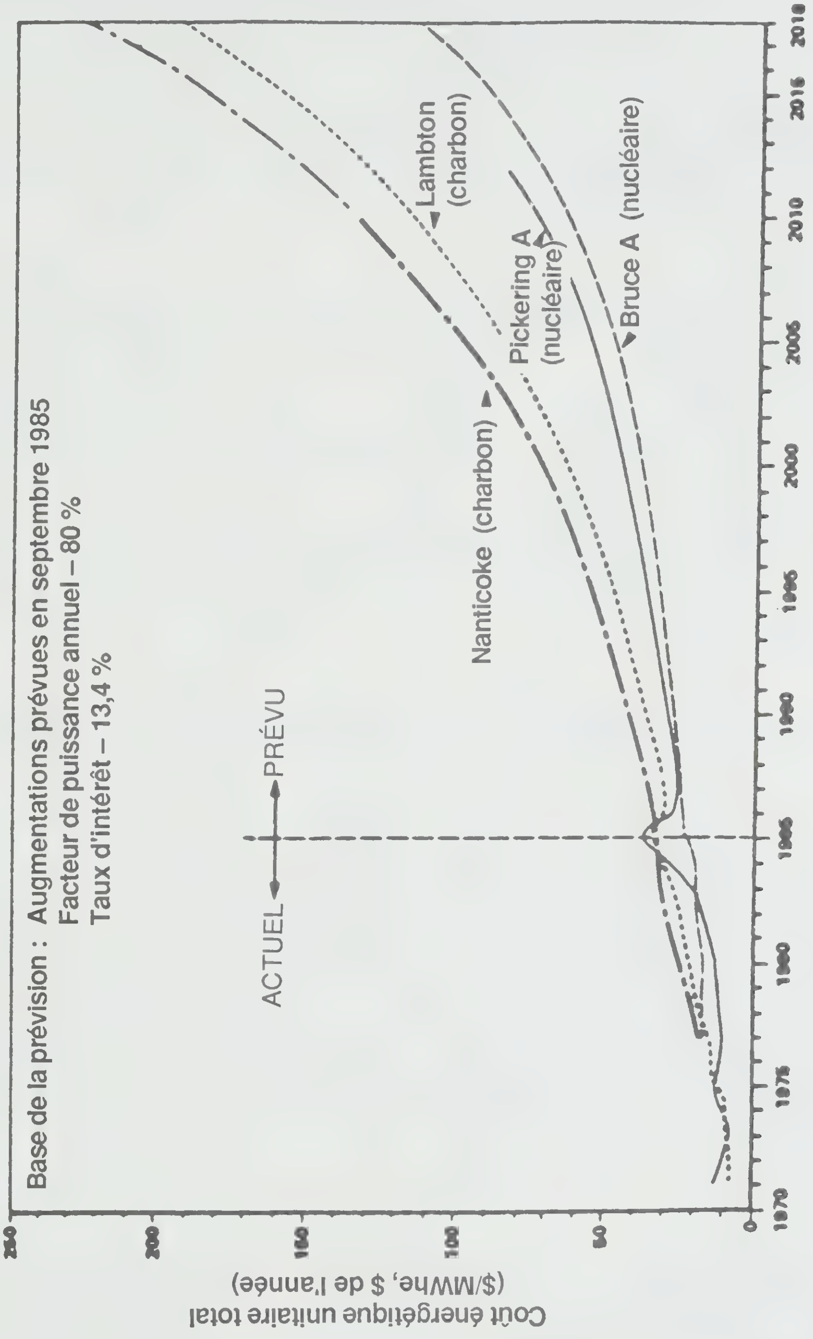
À partir de renseignements plus détaillés pour 1985, la dernière année pour laquelle ces données sont généralement disponibles, il est possible d'établir une comparaison économique intéressante. Le tableau 20 résume, centrale par centrale, les avantages en termes de coûts de la production d'électricité au moyen du nucléaire par rapport à des centrales comparables alimentées au charbon. La centrale Pickering A, moins les unités 1 et 2 hors service pour retubage, est comparée à la centrale thermique de Lambton (4 unités de 495 MWe mises en service en 1969-1970). La centrale Bruce A est comparée à la centrale thermique de Nanticoke (8 unités de 497 MWe, 1973-1978). Les centrales Pickering B et Bruce B sont comparées à une centrale au charbon hypothétique de capacité et de génération comparables que l'on suppose équipée d'épurateurs pour l'extraction du dioxyde de soufre (à l'heure actuelle, les centrales de Lambton et de Nanticoke ne sont pas équipées d'épurateurs).

Si l'on compte dans les calculs pour Pickering A les deux réacteurs à l'arrêt, la centrale thermique de Lambton présentait un avantage en termes de coûts de 35 %, en 1985, par rapport à Pickering A. Toutefois, dans le graphique de l'Ontario Hydro (graphique 1 dans Ontario Hydro, 1986a, p. 11, ou graphique 17 dans le présent rapport), le CEUT de Pickering est notablement inférieur à celui calculé à partir des données de 1985; l'Ontario Hydro a adopté une nouvelle règle de calcul en 1985 qui corrige le CEUT nucléaire «de façon à tenir compte du fonds d'amortissement pour l'enlèvement des canaux de combustible depuis le début de l'exploitation» (Ontario Hydro, 1986a, p. 10 et 12). Ce «lissage» des données nucléaires a tendance à cacher l'effet financier du retubage.

Plusieurs commentaires s'imposent concernant l'information présentée dans le tableau 20. Premièrement, l'avantage en termes de coûts de Pickering A, la plus ancienne des centrales CANDU à plusieurs unités, est moindre que celui des autres centrales nucléaires. Puisque le retubage des unités 1 et 2 mentionnées ne figure pas dans la comparaison, cela ne peut être attribuable qu'à des coûts d'exploitation, d'entretien et d'administration plus élevés pour la centrale Pickering A qui est plus ancienne. Il est plus étonnant encore de constater que les centrales plus récentes Pickering B et Bruce B présentent des avantages moindres en termes de coûts que la centrale Bruce A, bien qu'elles soient comparées à des centrales au charbon équipées d'épurateurs. Cela est attribuable aux coûts en capital relativement plus élevés des centrales Pickering B et Bruce B. Ces deux centrales ont un coût spécifique, mesuré en dollars courants par kilowatt de puissance nette installée, égal à plus du triple de celui de Bruce A (Ontario Hydro, 1986a, page 27).

Lorsque les données sont pondérées en utilisant les productions nettes d'électricité par centrale pour 1985, le CEUT pour le nucléaire est de 3,223, soit d'environ 15 % plus élevé que la valeur fournie pour 1985 au tableau 19. Cela réduirait à environ 20 % en 1985 l'avantage en termes de coûts du nucléaire par rapport au charbon. La diminution de l'avantage du nucléaire est attribuable à l'inclusion dans la

Graphique 17 : Coût énergétique unitaire total pour les principales centrales nucléaires et thermiques en exploitation dans le réseau de l'Ontario Hydro, 1970 -2018



Source : Ontario Hydro, *Economics of CANDU–PHW – 1985*, NGD–10, Toronto, août 1986, p. 24.

mégawatt-heure d'équivalent électrique aux centrales de Nanticoke et de Lambton alimentées au charbon et aux centrales nucléaires Pickering A et Bruce A.

Les projections du graphique 17 «excluent le reconditionnement probable des épurateurs pour l'extraction du SO_2 dans les centrales au charbon, mais elles tiennent compte du remplacement des tubes de force dans les centrales nucléaires» (Ontario Hydro, 1986a, page 23). Toutefois, lorsque ces prévisions ont été faites, l'Hydro n'avait pas anticipé le retubage rapide des unités 3 et 4 de la centrale Pickering A. L'accroissement du CEUT pour Pickering A, attribuable au retubage des unités 1 et 2, est évident dans le graphique 17; il serait utile de recalculer cette projection en tenant compte du retubage rapide des unités 3 et 4.

Les projections tiennent compte des coûts futurs associés au déclassement des centrales nucléaires et à l'évacuation du combustible épuisé. L'Ontario Hydro a introduit les coûts du déclassement ainsi que ceux du transport, du stockage et de l'évacuation du combustible irradié, dans ses calculs du coût de l'énergie nucléaire en 1982. Les coûts associés à l'enlèvement futur des tubes de force ont été introduits en 1984. En ce qui concerne les données de 1985 relatives à Pickering A, le coût énergétique unitaire était évalué à 0,64 $/MWhe pour le déclassement futur et à 0,73 $/MWhe pour le transport, le stockage et l'évacuation du combustible irradié. Le coût énergétique unitaire pour le remplacement des tubes de force était de 13,12 $/MWhe; le remplacement n'ayant pas été prévu, on n'en avait pas tenu compte dans les prévisions, ce qui se traduisit par une augmentation considérable du CEUT. En ce qui concerne les données de 1985 relatives à la centrale Bruce A, le coût énergétique unitaire était évalué à 0,15 $/MWhe pour le déclassement futur et à 0,k45 $/MWhe pour le transport, le stockage et l'évacuation du combustible épuisé. Le coût du remplacement futur des tubes de force était évalué à 0,50 $/MWh (Ontario Hydro, 1986a).

À partir de ces projections, l'Ontario Hydro a émis les conclusions suivantes (Ontario Hydro, 1986a, page 23) :

. les avantages en termes de coûts de la centrale nucléaire Pickering A devraient être rétablis une fois les tubes de force remplacés;

. les avantages en termes de charge de base du réacteur CANDU-PHWR devraient continuer;

. les avantages en termes de charge de base du réacteur CANDU-PHWR devraient augmenter;

. la caractéristique de «résistance à l'inflation» du réacteur CANDU-PHWR est indiquée.

tableau 19 englobe les coûts d'exploitation, d'entretien, d'administration et de combustible, ainsi que la dépréciation et les frais de financement. Sont exclus les coûts associés à la transmission, à la distribution et aux activités d'administration-gestion de l'entreprise. En ce qui concerne l'aspect nucléaire, sont aussi exclus les coûts attribuables au déclassement du réacteur et à l'évacuation du combustible épuisé.

Tableau 19 : Rendement économique des centrales nucléaires et alimentées aux combustibles fossiles de l'Ontario Hydro, 1982 à 1986

	Coût moyen (cents/kWh)		% d'avantage en termes de coûts
Année	**Nucléaire**	**Combustible fossiles**	**(nucléaire sur le charbon)**
1982	1,754	3,413	49 %
1983	1,874	3,371	44 %
1984	2,197	3,445	36 %
1985	2,794	4,043	31 %
1986	3,004	4,733	37 %

Remarque : Le coût moyen par kilowatt-heure englobe les coûts attribuables à la production, mais exclut les coûts associés à la transmission, à la distribution et aux activités d'administration gestion de l'entreprise. Ces valeurs reflètent les coûts comptables historiques de l'exploitation pendant les années mentionnées. Les coûts des combustibles fossiles englobent tous les coûts associés à l'utilisation du charbon, du pétrole et du gaz naturel.

Source : Ontario Hydro, *Inside Hydro*, Corporate Relations Branch, Toronto, décembre 1987, p. 109.

D'après ces renseignements, le coût de l'énergie nucléaire est inférieur à celui de l'énergie obtenue par les combustibles fossiles (en grande partie le charbon). Il est toutefois intéressant de noter que cet avantage du nucléaire a diminué pendant les quatre premières années mentionnées au tableau 19 pour ensuite quelque peu se rétablir en 1986 lorsque les unités qui étaient encore en construction à Pickering B et à Bruce B furent mises en service. Au bout de cinq années, le coût moyen de production d'un kilowatt-heure d'électricité à partir de l'énergie nucléaire s'était accru de 71,3 %, comparativement à 38,7 % pour la production à partir de combustibles fossiles. Il semble alors raisonnable de douter des prévisions à long terme de l'Ontario Hydro quant à un avantage croissant du nucléaire sur le charbon au niveau des coûts . Une telle projection est présentée au graphique 17 où l'on indique les prévisions jusqu'en 2018 des coûts énergétiques unitaires totaux en dollars courants par

d'énergie produite (en mégawatts-heures d'équivalent électrique, qui englobe l'électricité et l'équivalent électrique de l'énergie-vapeur utile produite à la centrale Bruce A).

La méthode du coût sur la **durée d'utilisation** est généralement utilisée pour comparer différents types de centrales futures. Le résultat est un coût annuel moyen exprimé en dollars constants et appelé **coût énergétique unitaire égalisé (CEUE)**. En 1984, le CEUE d'une unité CANDU de l'Ontario Hydro était de 21 millièmes de dollars le kWh comparativement à un CEUE de 33 millièmes de dollar le kWh pour une centrale alimentée au charbon. (Ceci pourrait être interprété comme un rendement «moyen» des centrales nucléaires par rapport aux centrales thermiques en Ontario). Dans certains rapports, le coût énergétique moyen sur la durée d'utilisation est exprimé en dollars constants par mégawatt-heure.

Les estimations des coûts mettant en cause les taux d'escompte et le coût en capital sont sujettes à révision à mesure que changent les conditions économiques et en particulier les taux d'intérêt. Les coûts de la main-d'oeuvre ont beaucoup augmenté à la fin des années 70 et des retards ainsi que des problèmes imprévus causés par des générateurs de vapeur défectueux ont retardé la mise en service des installations CANDU et en ont augmenté le coût.

En outre, les chiffres présentés ne sont pas entièrement comparables et l'inflation n'en est pas la seule raison. Une centrale mise en service plus tard que prévu ne coûte pas uniquement la somme de toutes les dépenses d'installation. Le coût de l'énergie de remplacement nécessaire en attendant une mise en service tardive doit également être pris en considération, tout comme l'importance d'une durée de vie reportée de plusieurs années dans le futur. Les retards de construction entraînent des frais financiers additionnels qui s'ajoutent au prix final. Enfin, et ceci découle de l'expérience canadienne restreinte, chaque centrale ayant ses coûts propres, on ne peut vraiment pas établir de coût moyen pour une installation nucléaire normalisée.

Une caractéristique commune aux mégaprojets en général, et aux centrales nucléaires canadiennes en particulier, est qu'il est impossible de prédire avec certitude ce que ces projets auront vraisemblablement coûté le jour de la mise en service et encore moins une fois leur durée d'exploitation écoulée. Si les rapports favorables d'organismes comme l'ÉACL et l'Ontario Hydro concernant la rentabilité sont vrais, cela indique qu'on a eu beaucoup de chance ou bien que l'énergie nucléaire est tellement supérieure sur le plan économique que des dépassements de coût de plusieurs milliards de dollars ne menacent pas la rentabilité économique d'un projet nucléaire.

Le tableau 19 permet de comparer le coût énergétique unitaire total (CEUT) de la production d'électricité à partir de l'énergie nucléaire à celui de la production à partir de combustibles fossiles (charbon, pétrole et gaz) dans le réseau de l'Ontario Hydro pendant la période de cinq ans allant de 1982 à 1986. Le coût moyen calculé au

combustion du charbon, et que les marchés continuent de s'adapter, le charbon indigène pourrait devenir une option viable pour le centre du Canada. Et le Canada, contrairement à la plupart des autres nations industrialisées, possède toujours des réserves hydro-électriques appréciables dans certaines régions du pays, y compris le Nord.

Un engagement à l'endroit de l'énergie nucléaire, du charbon ou de l'hydro-électricité ne se limite pas à engager des dépenses pendant la construction et la durée d'exploitation des centrales et des postes; c'est également l'abandon volontaire d'une technologie qui pourrait s'avérer préférable à mesure qu'elle se perfectionne et que les coûts en sont connus.

C. Indicateurs de coûts du nucléaire au Canada

Les réacteurs nucléaires au Canada présentent une bonne fiche économique en termes de coût énergétique unitaire normalisé. L'ÉACL et l'Ontario Hydro ont comparé les coûts passés d'installations nucléaires et alimentées au charbon en Ontario et ont constaté que les centrales nucléaires sont plus rentables aujourd'hui que les centrales thermiques comparables. L'écart prévu par Ontario Hydro grandira pendant les années 90 et les 25 premières années du siècle prochain, pour en arriver au point ou le coût du kilowatt-heure des centrales nucléaires ontariennes comme Pickering B et Bruce B sera plus de 50 % inférieur à celui des centrales thermiques comparables équipées d'épurateurs par voie humide.

Malgré tout, le dossier économique du développement du nucléaire au Canada a été moins reluisant que prévu. Des dépassements de devis atteignant des proportions considérables ont caractérisé les installations nucléaires. Pickering B, coût estimé 1 585 millions de dollars, coût réel 3 862 millions (cinq fois plus que Pickering A); Bruce B, coût estimé 3 869 millions de dollars, coût réel 6 036 millions avec une mise en service deux ans plus tard que prévu; Point Lepreau, coût estimé 466 millions de dollars, coût réel 1 448 millions et quatre ans de retard. Néanmoins, des études de l'ÉACL et de l'Ontario Hydro indiquent que les réacteurs nucléaires canadiens sont plus rentables que leurs homologues alimentés au charbon.

Les services publics d'électricité au Canada utilisent généralement deux méthodes pour exprimer les coûts de production. Dans la méthode du **coût annuel**, les coûts de production réels, dans des centrales existantes ou futures, sont évalués en dollars courants, avec des hypothèses au sujet des taux d'inflation et des taux d'intérêt futurs. Le résultat est une projection des coûts de production annuels variant au cours de la vie d'une centrale. Cette méthode est dite méthode du **coût énergétique unitaire total (CEUT)**. Pour l'Ontario Hydro, le CEUT est défini comme étant le coût total annuel de la production d'énergie (en dollars courants) divisé par la quantité totale annuelle

peuvent modifier la perspective, mais l'étude de l'AIEA sur les nouvelles expansions de la capacité de production d'électricité confirme cette alternative fondamentale, au moins à court terme.

Dans un grand nombre de pays, l'hydro-électricité n'est plus une option puisque des barrages ont déjà été construits aux emplacements les plus prometteurs ou que des considérations environnementales interdisent tout autre aménagement. La phase II du projet hydro-électrique de la baie James au Québec constitue toutefois une exception notable à cette règle.

La plupart des pays ne sont pas prêts aujourd'hui à accepter le risque, en termes de prix et de sécurité d'approvisionnement, que pose l'utilisation du pétrole importé pour accroître leur puissance de base. Les pays qui peuvent compter sur des approvisionnements en gaz naturel utilisent le gaz pour couvrir les périodes de pointe ou même pour accroître leur puissance de base. Cependant, le gaz naturel n'est pas aussi disponible ou aussi bon marché que le charbon pour la production d'électricité.

Il ne reste donc que le charbon et l'énergie nucléaire pour un grand nombre de pays. L'énergie nucléaire est économiquement préférée pour la production continue d'électricité en régime de base alors que le charbon est mieux adapté à la production temporaire ou en période de pointe. Néanmoins, les Français ont démontré que les réacteurs nucléaires pouvaient fonctionner en suivi de charge.

Certains pays ont accepté d'emblée l'énergie nucléaire faute d'autres solutions; par contre, au Canada, le charbon est abondant et les technologies du transport et de la combustion plus propre en font une solution viable et concurrentielle. D'après certains fonctionnaires avec qui les membres du Comité se sont entretenus en Suède, en Allemagne fédérale et en France, l'énergie nucléaire est nettement la source de production d'électricité à grande échelle la moins coûteuse à l'heure actuelle et elle est considérée (sauf en Suède) comme un élément nécessaire de toute stratégie visant à satisfaire la demande d'électricité jusqu'au siècle prochain. À cause de questions plus émotives, certains programmes nucléaires à l'étranger s'embourbent.

Au Canada, la question économique que pose l'utilisation du charbon plutôt que celle de l'énergie nucléaire est une question essentiellement régionale. Le nucléaire présente un avantage à long terme au niveau des coûts pour l'Ontario Hydro et la Commission d'énergie électrique du Nouveau-Brunswick, selon les experts de l'exploitation des installations nucléaires. Le système CANDU se mérite de bonnes cotes en matière de rendement, de fiabilité et de sécurité, facteurs clés de toute décision d'investissement. Cependant, le charbon est de toute évidence le meilleur choix dans d'autres régions, notamment là où des centrales peuvent être construites à côté ou à proximité de mines de charbon à ciel ouvert comme en Alberta et en Saskatchewan. À mesure que s'améliorent les technologies de la préparation, du transport et de la

au secteur privé et doivent se financer par la vente d'actions, les entreprises canadiennes dépendent des gouvernements provinciaux pour ce qui est des décisions ultimes en matière de stratégie d'expansion et des capitaux propres.

L'investissement indirect, par lequel des investisseurs achètent des obligations à long terme émises par les entreprises provinciales de services publics, constitue une source majeure de fonds pour les entreprises canadiennes. Une proportion élevée de ces obligations sont émises à l'étranger. Le fait que les entreprises canadiennes de services publics comptent sur l'investissement indirect explique leur ratio d'autonomie financière plus élevé.

Dans la mesure où des gouvernements provinciaux garantissent des emprunts à leurs entreprises de services publics, ces entreprises sont dans une meilleure position face à l'investissement que leurs contreparties américaines. La cote de crédit d'une entreprise canadienne de service public est directement reliée à la cote de crédit de la province mère. Il existe une autre différence : les actifs des entreprises canadiennes de services publics ne sont pas autant concentrés dans le domaine nucléaire que le sont ceux de certaines entreprises américaines de services publics, quoique les 38 % de l'actif immobilisé de l'Ontario Hydro que représentent ses centrales nucléaires constituent un montant important.

Une autre différence majeure est le rendement supérieur des centrales canadiennes. À la fin de juin 1987, les réacteurs canadiens avaient atteint un facteur de charge cumulatif moyen de 78,7 %. Seules la Suisse (79,7 %) et la Finlande (79,3 %), parmi les pays non communistes exploitant quatre centrales ou plus, avaient dépassé ce rendement. Même en considérant le facteur de charge moyen pour la période de 12 mois se terminant le 30 juin 1987 (afin de tenir compte de la fermeture des unités Pickering 1 et 2 pour retubage), le résultat était de 71,4 %.

Néanmoins, en comparant les coûts du nucléaire à ceux des autres technologies, le coût en capital des installations nucléaires devrait être corrigé en fonction du risque. Puisque tout porte à croire que de telles primes de risque sont exigées par les investisseurs du secteur privé, les décisions des entreprises de services publics au Canada devraient refléter les coûts réels sur le marché, même si ces coûts peuvent ne pas se manifester de manière aussi explicite que dans les entreprises privées de services publics aux États-Unis.

B. Le nucléaire par rapport au charbon

Dans le monde occidental industrialisé, le choix en matière d'expansion de la capacité de production d'électricité, au cours des prochaines décennies, est entre les centrales alimentées au charbon et les centrales nucléaires. Des facteurs régionaux

Il y a plusieurs années, la *U.S. Federal Energy Regulatory Commission* (FERC) permettait à la *Connecticut Yankee Atomic Energy Corporation* un rendement des capitaux propres de 17 %, ce qui était à l'époque le rendement le plus élevé jamais accordé à une entreprise américaine de service public productrice d'électricité. La FERC a invoqué dans cette décision le risque associé à l'énergie nucléaire au lendemain de l'accident de Three Mile Island; les investisseurs s'estiment peu protégés lorsque le seul actif d'un service public est un réacteur nucléaire (États-Unis, DOE, EIA, 1984).

Trois événements ayant contribué à l'établissement d'une prime de risque pour l'énergie nucléaire sont mentionnés dans une étude réalisée en 1984 par le département de l'Énergie des É.-U. et intitulée *Investor Perceptions of Nuclear Power* : 1) l'accident de Three Mile Island de mars 1979; 2) la prise de conscience ultérieure du fait que les coûts de nettoyage après un accident de l'ampleur de celui de Three Mile Island pourraient dépasser 1 milliard de dollars US et ne seraient pas entièrement assurables, ce qui pourrait entrainer des pertes considérables; 3) les décisions prises en 1982 par la *Tenessee Valley Authority* d'annuler certains de ses projets de construction de centrales nucléaires et par la *Nuclear Regulatory Commission* d'arrêter les travaux au réacteur Zimmer, avec un avertissement quant à la fermeture possible des réacteurs 2 et 3 à Indian Point (États-Unis, DOE, EIA, 1984).

Cette étude suggère qu'en raison de l'accident à Three Mile Island, la valeur d'un investissement dans une entreprise nucléaire de service public aurait diminué de 10 % par rapport à celle d'un investissement dans une entreprise non nucléaire de service public. Une telle diminution pourrait découler du fait que les investisseurs qui achètent réellement de tels titres veulent une prime au rendement de un ou deux points de pourcentage. Deux autres facteurs ont contribué à accroitre l'inquiétude des investisseurs. En premier lieu, à la fin de 1982, les annulations de centrales nucléaires avaient coûté 15 milliards de dollars US; selon les estimations, les investisseurs avaient absorbé 30 % de ces coûts. En second lieu, les centrales nucléaires américaines avaient fonctionné en moyenne à seulement un peu plus de 55 % de leur capacité nominale [le facteur de charge cumulatif moyen pour tous les réacteurs américains de 150 Mwe et plus était de 56,6 % à la fin de juin 1987], alors que dans des études de coût comparatives, on supposait un facteur de charge de 70 %. Les actionnaires doivent aussi assumer une partie des coûts entrainés par ce rendement effectif inférieur au rendement prévu (États-Unis, DOE, EIA, 1984).

Que signifient ces conclusions américaines pour l'investissement dans les installations nucléaires canadiennes? La structure de l'industrie canadienne de l'énergie électrique diffère à plusieurs égards de celle de cette industrie aux États-Unis. Le fait que la plupart des entreprises canadiennes de services publics sont de propriété publique signifie que leurs actions ne sont pas échangées sur le marché boursier. À l'opposé des entreprises américaines de services publics dont la plupart appartiennent

LES ASPECTS ÉCONOMIQUES DE L'ÉNERGIE NUCLÉAIRE

Plus les pays occidentaux ont acquis de l'expérience dans l'exploitation des centrales atomiques, plus le nucléaire a été un sujet controversé. Les divers groupes d'intérêt ont exprimé leur inquiétude au sujet de l'environnement et de la sécurité, mais l'aspect le plus critique du débat entourant le nucléaire est l'aspect économique puisque c'est là que les promesses de l'énergie nucléaire n'ont pas été entièrement réalisées. Des progrès relatifs ont été accomplis dans les technologies concurrentielles de production d'électricité tant au niveau du rendement qu'à celui des coûts, en particulier aux États-Unis.

A. L'économique du risque

Le débat public sur l'énergie nucléaire porte en grande partie sur des préoccupations techniques et sur la probabilité, ou le «risque», d'un accident nucléaire. Le mot risque a un tout autre sens lorsqu'on parle des aspects financiers de l'énergie nucléaire. Le risque économique réfère plutôt à la variabilité du rendement prévu d'un investissement. La question est alors : «Les installations nucléaires comportent-elles des risques économiques plus élevés que les technologies non nucléaires pour la production d'énergie électrique?»

Il est de plus en plus évident, en particulier dans des études effectuées aux États-Unis, que les facteurs de risque sont plus élevés pour les installations nucléaires que pour les installations non nucléaires de production d'électricité, même si les services publics possédant des centrales nucléaires ne constituent pas nécessairement un mauvais investissement lorsque toutes les occasions sur le marché des capitaux sont prises en considération. Si les investisseurs perçoivent un risque plus grand dans le nucléaire que dans le non nucléaire pour la production d'énergie électrique, le coût en capital des projets nucléaires — que l'on suppose généralement uniforme aux fins des études de comparaison des coûts de production d'énergie électrique — sera plus élevé puisque le taux de rentabilité des investissements constitue une part importante du coût en capital.

Plusieurs grandes sociétés américaines d'investissement suggèrent que le risque économique est en effet plus élevé dans le cas des centrales nucléaires. Après l'accident de Three Mile Island, la *Merrill Lynch* a conclu que les investisseurs institutionnels considèrent comme un facteur de risque l'utilisation de l'énergie nucléaire par une entreprise de service public. D'autres courtiers, comme la *Salomon Brothers*, conseillent à leurs clients de se méfier des sociétés possédant des installations nucléaires.

vérification du concept sera terminée, la CCÉA se prononcera sur l'acceptabilité du concept. La Commission a aussi décidé qu'elle appliquerait la même procédure de délivrance de permis à un site d'enfouissement qu'à n'importe quelle autre installation nucléaire. Par conséquent, la population devra être informée avant que le site ne soit choisi; le site proposé devra être approuvé par la CCÉA; et la Commission devra donner son aval pour l'aménagement du site, pour le dépôt des matières radioactives dans le site d'enfouissement, pour l'exploitation du site à l'échelle commerciale et pour le contrôle et la surveillance éventuelle du site.

La CCÉA a énoncé une politique pour la réglementation de l'évacuation des déchets radioactifs à long terme (Canada, CCÉA, 1987a). Les principaux objectifs de l'évacuation des déchets radioactifs sont les suivants :

. réduire au minimum le fardeau imposé aux générations futures,

. protéger l'environnement

. protéger la santé

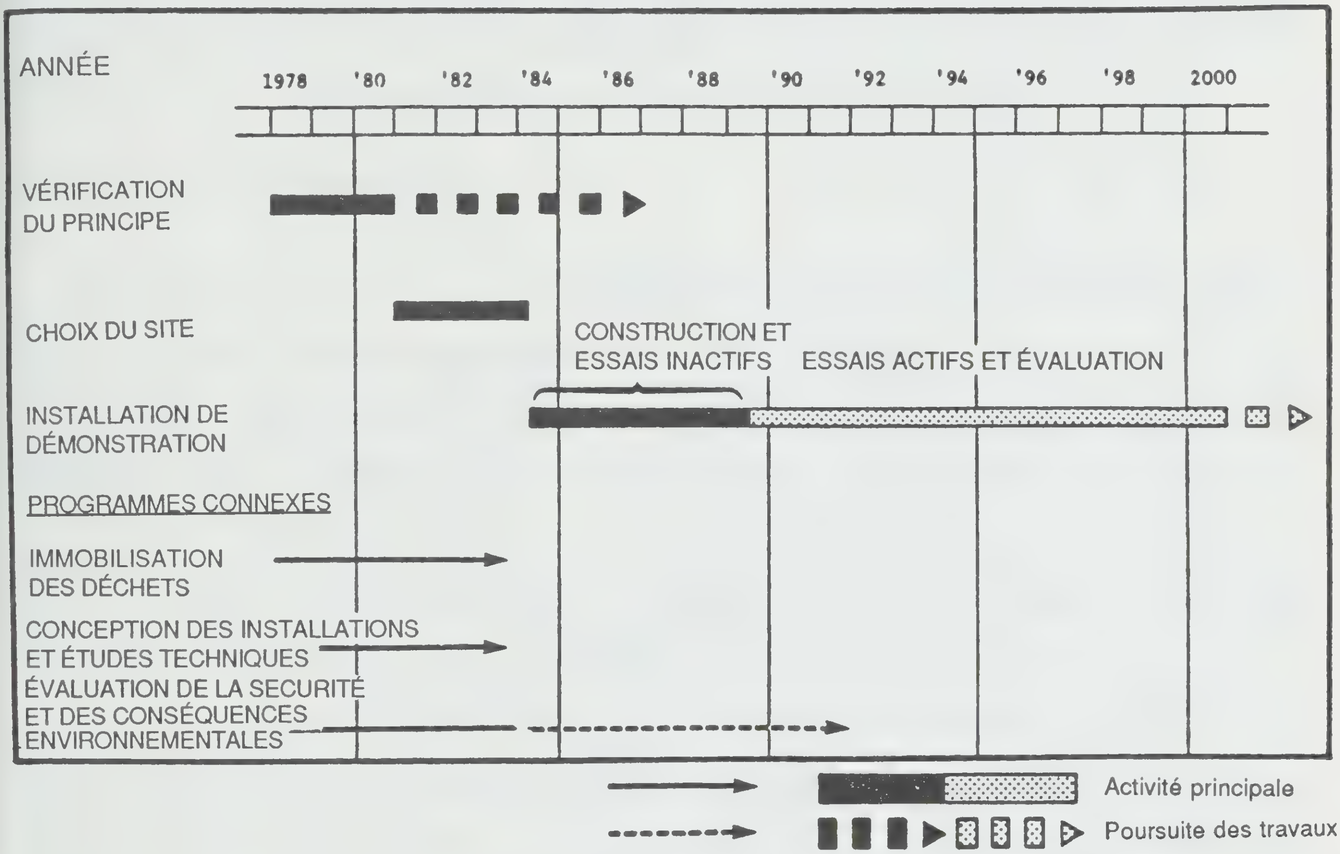
compte tenu des facteurs sociaux et économiques.

Dans un communiqué du mois de juin 1988, le gouvernement fédéral annonçait un examen environnemental de la gestion à long terme des déchets radioactifs au Canada. Le ministre de l'Environnement créera un Comité fédéral d'examen des évaluations environnementales dont le mandat sera d'examiner lors d'audiences publiques les incidences sociales, économiques et environnementales de la gestion des déchets radioactifs à long terme. D'autre part, un groupe indépendant d'experts sera formé pour faire un examen scientifique et technique détaillé du concept de la méthode canadienne d'enfouissement. Les résultats de cet examen seront communiqués au Comité. En supposant que le Comité formule ses directives en 1989, l'ÉACL prévoit soumettre sa documentation sur l'évaluation du concept au Comité et à la Commission de contrôle de l'énergie atomique en 1991. Des audiences publiques seront alors tenues par le Comité pour examiner l'évaluation d'ÉACL. Les études des différents sites ne seront vraisemblablement pas entreprises avant que la phase d'évaluation n'ait terminé avec succès ce processus d'examen public.

Peu de temps avant de terminer le présent rapport, le Comité a appris que le gouvernement suisse avait officiellement reconnu le principe de l'enfouissement des déchets radioactifs. La Suède et la Suisse sont les seuls pays ayant des centrales nucléaires à exiger une démonstration d'élimination sûre. Tous deux ont annoncé que les critères exigés avaient été satisfaits. La Suède et la Suisse prévoient enfouir leur déchets radioactifs dans des formations géologiques profondes et stables, comme le fait le Canada.

Les hôtes suédois du Comité ont souligné que le CCT avait été invité à donner son avis sur le programme suédois de gestion des déchets radioactifs et qu'il l'avait fait pour le plus grand bien du programme.

Graphique 16 : Calendrier établi en 1978 pour le Programme d'élimination du combustible épuisé



Source : Boulton, J. (éd.), *Management of Radioactive Fuel Wastes: The Canadian Disposal Program*, AECL–6314, Établissement de recherches nucléaires de Whiteshell, Société de recherche de l'Énergie atomique du Canada, Limitée, Pinawa (Manitoba), octobre 1978, p. 60.

La Commission de contrôle de l'énergie atomique joue un rôle fondamental dans la mise au point d'une technologie appropriée de gestion des déchets. Lorsque la

Un projet de calendrier a été établi pour le volet élimination du programme. Les cibles particulières (Boulton, 1978, p. 59 et 61) sont :

a) vérifier d'ici 1981 les concepts de base de l'élimination du combustible irradié ou des déchets combustibles dans la roche dure profonde, au moins dans la mesure d'un consensus général;

b) recommander des sites techniquement acceptables parmi lesquels les gouvernements pourront choisir un site définitif et aménager un site d'enfouissement de démonstration d'ici 1985;

c) perfectionner le site de démonstration jusqu'à un point où la construction d'un site d'enfouissement à l'échelle réelle pourra être envisagée d'ici l'an 2000.

Le graphique 16 décrit le calendrier publié en 1978 pour le programme expérimental d'élimination des déchets. À l'époque, ce calendrier a été jugé trop optimiste, notamment par la communauté scientifique qui était en mesure de cerner l'ampleur de l'effort de R et D nécessaire pour la première étape, soit la vérification du concept. Le temps a donné raison à la critique.

Le retard que connaît le programme d'élimination des déchets radioactifs ne constitue pas un problème de sécurité publique. Les méthodes d'entreposage temporaire du combustible épuisé se sont avérées assez satisfaisantes et pourraient être utilisées pendant une période indéfinie. Les retards enregistrés ont pour effet de réduire la confiance du public dans le programme de gestion des déchets, de rendre la population encore plus incertaine des progrès réalisés et d'augmenter le coût total de la recherche consacrée au programme.

La responsabilité de la R et D revient surtout à l'ÉACL. Dans le passé, l'ÉACL effectuait la recherche presque entièrement au sein même de son établissement; de nos jours, elle fait aussi appel à des chercheurs de l'extérieur. Un bon nombre d'entreprises privées et d'universités apportent une contribution technique importante au programme.

L'ÉACL a publié chaque année, et publie maintenant tous les six mois, un rapport sur l'avancement de son programme de gestion des déchets; chaque année, un Comité consultatif technique (CCT) indépendant se prononce sur la pertinence du programme canadien. Le CCT est composé de dix membres, choisis à même une liste de candidats soumis par les grandes sociétés scientifiques et de génie du Canada. Quatre caractéristiques de son fonctionnement garantissent son autonomie. Premièrement, seules peuvent être membres du CCT les personnes recommandées par des sociétés savantes canadiennes. Deuxièmement, le CCT fait publiquement rapport chaque année. Troisièmement, les membres du CCT ont entièrement droit de regard sur tous les aspects du programme de recherche. Quatrièmement, le CCT dispose de ressources pour obtenir l'avis d'autres spécialistes ou d'experts-conseils, lorsqu'il en éprouve le besoin.

Le programme canadien de gestion des déchets radioactifs est mené en vertu d'une entente conjointe entre le gouvernement fédéral et le gouvernement de l'Ontario, entente qui a été annoncée le 5 juin 1978. Cette entente définit quatre grands secteurs de responsabilité en matière de gestion de tels déchets. Le gouvernement de l'Ontario, par l'intermédiaire de son agence Ontario Hydro, est chargé du stockage temporaire des déchets radioactifs et de l'organisation d'un système de transport de ces déchets. Le gouvernement fédéral, par l'intermédiaire de son agence l'ÉACL, est chargé de mettre au point la technologie pour immobiliser les déchets radioactifs et de trouver un moyen convenable de les éliminer de façon permanente.

Le but du volet élimination du programme conjoint «est de s'assurer que l'élimination permanente dans un site d'enfouissement souterrain profond situé dans la roche ignée intrusive est une méthode sûre, sécuritaire et désirable d'éliminer les déchets radioactifs». La méthode d'élimination finale est actuellement mise au point par ÉACL, en consultation avec d'autres organismes. Ce programme comporte quatre étapes : la vérification du concept; le choix et l'acquisition du site; la démonstration de la méthode d'élimination; et l'exploitation du site.

La vérification du concept, qui est en cours, a pour but de s'assurer que le concept de l'enfouissement géologique profond constituera une solution sûre et acceptable sur le plan environnemental. Sous la direction d'ÉACL, la vérification du concept se fait par des organismes fédéraux et provinciaux, des universités et des entreprises industrielles privées.

La deuxième étape est celle du choix et de l'acquisition du site. Selon ce que révélera la vérification du concept, différents sites seront retenus en vue d'essais plus poussés, en consultation avec les collectivités concernées. Le mécanisme par lequel ce choix sera arrêté n'a pas encore été établi, mais comportera vraisemblablement de longues audiences publiques. On devra, à un moment donné, faire le choix et l'acquisition d'un seul site.

La troisième étape est celle de la démonstration de la méthode d'élimination au site choisi. Il est prévu que l'installation d'élimination souterraine sera expérimentée durant une longue période, autant pour vérifier les hypothèses scientifiques élaborées pendant la vérification du concept que pour vérifier si le site choisi est acceptable. Cette étape comprendra aussi la construction d'une usine-pilote d'immobilisation des déchets avant que ces derniers ne soient déposés dans le site d'enfouissement permanent.

La dernière étape est celle de l'exploitation commerciale d'une installation d'élimination. Elle ne prendra place qu'après que la méthode d'élimination aura été jugée convenable pour ce site. Il semble probable qu'une seule installation sera construite pour traiter le combustible épuisé des réacteurs de puissance de l'Ontario, du Québec et du Nouveau-Brunswick.

Tableau 18 : Accumulation du combustible nucléaire irradié au Canada

Used Nuclear Fuel in Canada

Nombre de faisceaux

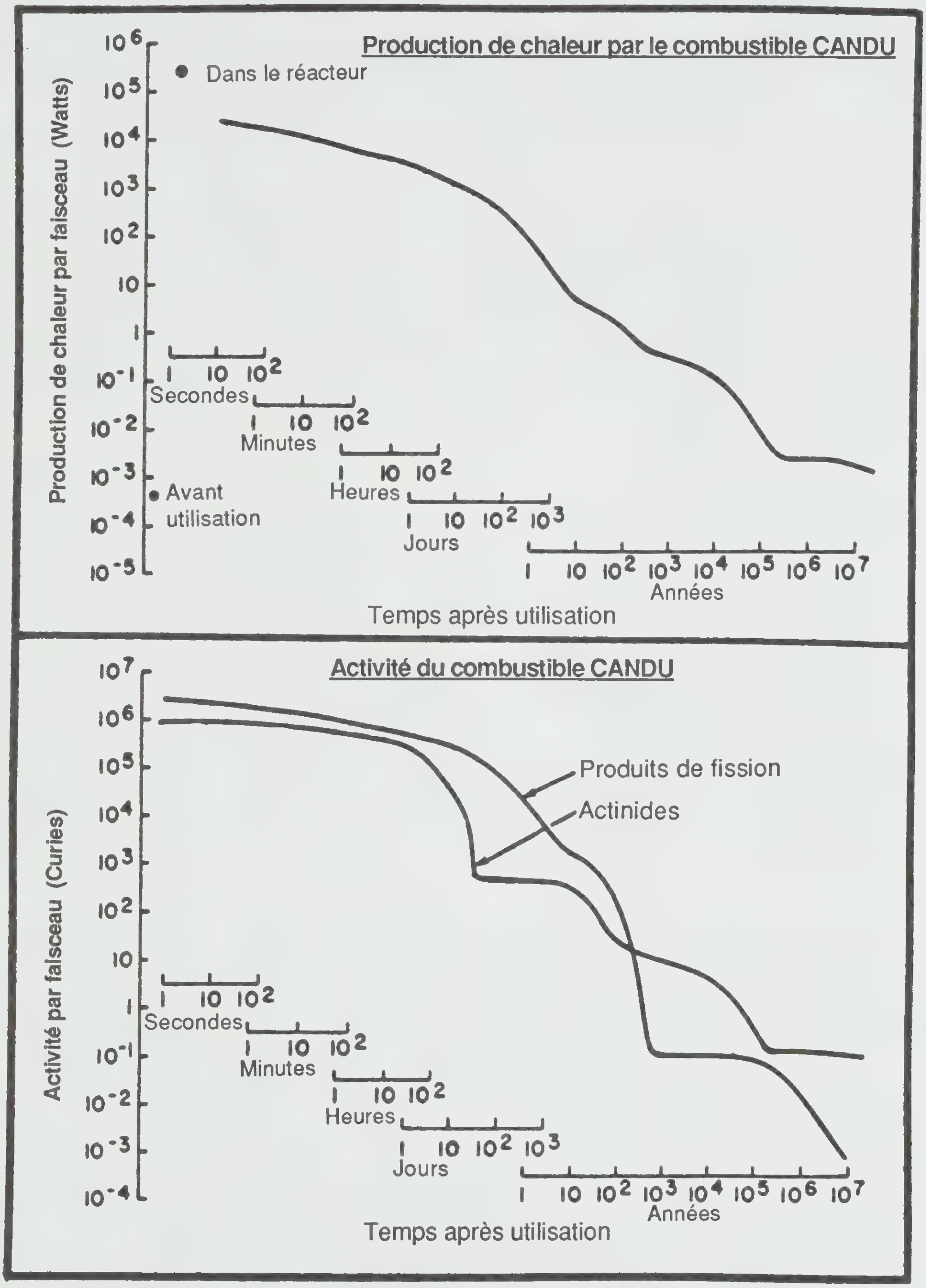
	Décembre 1987	2050 (projection)
Ontario Hydro	475 000	3 700 000
Hydro-Québec	19 700	315 000
N.B. Power	20 000	335 000
Total	**514 700**	**4 350 000**

Notes : a) Chaque faisceau de combustible contient 20 kg d'oxyde d'uranium et occupe un volume de 0,005 m^3.

b) Les projections sont basées sur les réacteurs actuellement en exploitation et en construction.

Source : Communication personelle : Eva Rossinger, Établissement de recherches nucléaires de Whiteshell, ÉACL, Pinawa (Manitoba), 4 juillet 1988.

Graphique 15 : Production de chaleur et niveaux de radioactivité du combustible CANDU irradié



Source : Boulton, J. (éd.), *Management of Radioactive Fuel Wastes: The Canadian Disposal Program*, AECL–6314, Établissement de recherches nucléaires de Whiteshell, Société de recherche de l'Énergie atomique du Canada, Limitée, Pinawa (Manitoba), octobre 1978, p. 20.

Le tableau 18, fourni par l'Établissement de recherches nucléaires de Whiteshell de l'ÉACL, contient des données sur la quantité de combustible irradié qui doit être évacuée au Canada. La première colonne donne la quantité de combustible épuisé produit jusqu'à la fin de 1987, par service public d'électricité; la seconde colonne contient des projections de ce que seront ces quantités en 2050, compte tenu des réacteurs de puissance canadiens actuellement en exploitation et en construction.

On peut penser que 4,35 millions de faisceaux de combustible épuisé est un chiffre élevé, mais, à raison de 20 kilogrammes d'oxyde d'uranium par faisceau, cela correspond à 87 000 tonnes. À titre de comparaison, les installations de la Syncrude dans les sables pétrolifères de l'Alberta, fonctionnant à plein rendement, peuvent extraire et traiter plus de 100 000 tonnes de sable pétrolifère pendant un poste de travail de 8 heures. [À plein rendement, la Syncrude peut extraire et traiter 300 000 tonnes de sable bitumineux et produire 175 000 barils de bitume en 24 heures.] Ainsi, la quantité de combustible épuisé à gérer est importante, mais en aucune façon exhorbitante.

Le combustible irradié est retiré du coeur du réacteur à l'aide d'un télémanipulateur, puis transféré dans un bassin de stockage rempli d'eau. La protection contre le rayonnement est assurée par les quelque quatre mètres d'eau qui recouvrent les faisceaux de combustible et par les épaisses parois en béton du bassin. Cette méthode, couramment appelée «stockage par voie humide», est utilisée un peu partout au monde depuis plus de 40 ans et constitue un moyen sûr pour stocker et récupérer ultérieurement le combustible pendant qu'il refroidit et que son niveau de radioactivité diminue. Toutefois, ces bassins ont un coût de construction élevé et exigent l'application d'importantes mesures d'entretien et de contrôle. L'ÉACL a été la première à essayer une nouvelle méthode, appelée «stockage par voie sèche», comportant le transfert du combustible épuisé dans des conteneurs renforcés de béton ayant la forme de silos d'environ 6 mètres de hauteur et 2,5 mètres de diamètre. Des rangées de conteneurs sont aménagées sur de béton, puis le combustible épuisé est introduit dans ces conteneurs qui sont ensuite fermés hermétiquement. La chaleur est éliminée par refroidissement convectif naturel à l'air. La méthode de stockage par voie sèche permet de réaliser des économies considérables; les conteneurs ont une durée utile prévue d'au moins 50 ans. Le stockage par voie sèche constitue donc une solution attrayante dans le cadre d'une stratégie de mise hors service différée. Ce concept a été éprouvé à l'Établissement de recherches nucléaires de Whiteshell et a depuis été utilisé pour stocker du combustible épuisé aux centrales de Gentilly-1 et de Douglas Point, ainsi qu'à Chalk River. Il a fallu onze conteneurs pour stocker le combustible épuisé à Gentilly-1; vu la plus grande quantité de combustible irradié provenant de Douglas Point, il a été nécessaire de construire 47 conteneurs un peu plus gros.

La chaleur totale produite par un faisceau de combustible irradié CANDU, une fois retiré du réacteur, est représentée en fonction du temps dans la moitié supérieure du graphique 15, et les niveaux d'activité des produits de fission et des actinides après le retrait du combustible hors du réacteur sont représentés en fonction du temps dans la moitié inférieure du graphique 15. Ces valeurs sont caractéristiques du combustible CANDU après une consommation moyenne de 7,500 mégawatts-jours/tonne d'uranium. L'échelle de temps est logarithmique et s'étend d'une seconde à 10 millions d'années. L'échelle des ordonnées qui représente la production de chaleur dans le diagramme de la moitié supérieure et la radioactivité dans le diagramme de la moitié inférieure est aussi logarithmique et couvre 11 ordres de grandeur.

Tableau 17 : Certains actinides dans le combustible irradié CANDU

Radionucléide	Période (ans)	Activité (curies/kilogramme d'uranium) lors du rejet	après 1 an	après 10 ans	Rayonnements importants
Neptunium 237	$2,1 \times 10^{6}$	$2,1 \times 10^{-5}$	$2,1 \times 10^{-5}$	$2,2 \times 10^{-5}$	alpha, gamma
Plutonium 238	87,7	$7,2 \times 10^{-2}$	$8,3 \times 10^{-3}$	$8,0 \times 10^{-2}$	alpha, gamma
Plutonium 239•	$2,4 \times 10^{4}$	0,15	0,15	0,15	alpha, gamma
Plutonium 240	$6,8 \times 10^{3}$	0,24	0,24	0,24	alpha, gamma
Plutonium 241•	14,7	22,9	21,8	14,2	bêta, gamma
Américium 241	432	$11,5 \times 10^{-3}$	$4,7 \times 10^{-2}$	0,3	alpha, gamma
Américium 243	$7,4 \times 10^{3}$	$5,3 \times 10^{-4}$	$5,3 \times 10^{-4}$	$5,3 \times 10^{-4}$	alpha, gamma
Curium 242	0,45	2,58	0,44	$8,9 \times 10^{-6}$	alpha, gamma
Curium 244	18,1	$1,6 \times 10^{-2}$	$1,5 \times 10^{-2}$	$1,1 \times 10^{-2}$	alpha, gamma

• actinide fissile

Source : Boulton, J. (éd.), *Management of Radioactive Fuel Wastes: The Canadian Disposal Program*, AECL–6314, Établissement de recherches nucléaires de Whiteshell, Société de recherche de l'Énergie atomique du Canada, Limitée, Pinawa (Manitoba), octobre 1978, p. 19.

Le graphique 15 révèle que la production de chaleur d'un faisceau de combustible CANDU irradié, une fois retiré du réacteur, est tombée à moins d'un millième de sa valeur initiale après trois ans environ. La radioactivité atteint à peine 1/10 000 de sa valeur initiale après 100 ans environ.

décennie, à mesure que les radionucléides de courte période se font rares. Après 200 ans environ, l'activité des produits de fission chute en-deçà de l'activité des actinides, ces derniers devenant désormais les principales sources de radioactivité. L'activité des produits de fission continue de chuter rapidement et, après 500 ans, cette activité est d'environ 1/100 000 de sa valeur initiale. L'activité des actinides diminue lentement et, après 500 ans, atteint environ 1/15 de sa valeur initiale. Le stockage à court terme dans l'eau, au site même des réacteurs, permet de diminuer le danger des produits de fission, tandis que l'élimination du combustible épuisé est recommandée pour empêcher les actinides de s'échapper d'un site d'enfouissement permament.

Tableau 16 : Certains produits de fission dans le combustible irradié CANDU

Radionucléide	Période (ans)	Activité (curies/kilogramme d'uranium) lors du rejet	après 1 an	après 10 ans	Rayonnements importants
Tritium (H–3)	12,3	0,17	0,16	0,10	bêta
Krypton 85	10,7	2,22	2,19	1,23	bêta, gamma
Strontium 89	0,14	443	3,95	$9,8 \times 10^{-20}$	bêta, gamma
Strontium 90	29	17,5	16,0	12,9	bêta
Yttrium 91	0,16	578	77	$1,1 \times 10^{-16}$	bêta, gamma
Zirconium 95	0,18	825	17,3	$1,3 \times 10^{-14}$	bêta, gamma
Niobium 95	0,10	802	36,6	$2,9 \times 10^{-14}$	bêta, gamma
Technétium 99	$2,1 \times 10^{5}$	$3,4 \times 10^{-3}$	$3,4 \times 10^{-3}$	$3,4 \times 10^{-3}$	bêta, gamma
Ruthénium 106	1,0	182	101	0,21	bêta
Iode 129	$1,6 \times 10^{7}$	$7,9 \times 10^{-6}$	$7,9 \times 10^{-6}$	$7,9 \times 10^{-6}$	bêta, gamma
Iode 131	0,02	525	$1,2 \times 10^{-11}$	0	bêta, gamma
Césium 134	2,17	16,9	11,3	0,55	bêta, gamma
Césium 135	$2,3 \times 10^{6}$	$4,5 \times 10^{-5}$	$3,8 \times 10^{-5}$	$3,8 \times 10^{-5}$	bêta
Césium 137	30,2	25,3	24,8	20,2	bêta, gamma
Cérium 144	0,78	424	181	0,06	bêta, gamma
Prométhium 147	2,6	58,9	50,7	4,7	bêta, gamma

Source : Boulton, J. (éd.), *Management of Radioactive Fuel Wastes: The Canadian Disposal Program*, AECL–6314, Établissement de recherches nucléaires de Whiteshell, Société de recherche de l'Énergie atomique du Canada, Limitée, Pinawa (Manitoba), octobre 1978, p. 19.

Tableau 15 : Composition d'un faisceau de combustible CANDU avant et après irradiation

Constituant	Nouveau combustible (grammes)	Combustible irradié (grammes)
Actinides		
Uranium 238	18 865	18 725
Uranium 235	134	44
Autres isotopes de l'uranium	1	15
Plutonium	-	71
Autres actinides	-	1
Produits de fission		
Iode	-	1
Césium	-	11
Technétium	-	4
Autres produits de fission	-	128
Total	**19 000**	**19 000**

Source : Communication personelle : William T. Hancox, Société de recherche de l'ÉACL, Ottawa, 9 février 1988.

La plupart des produits de fission nouvellement produits sont inactifs. Le combustible rejeté contient 98,85 % d'oxyde d'uranium en poids; les 1,15 % restants — constitués essentiellement de produits de fission et de divers isotopes du plutonium — comprennent 0,65 % de produits de fission inactifs, 0,11 % de produits de fission actifs et 0,38 % de plutonium.

Lorsque le combustible épuisé est retiré pour la première fois du réacteur, la radioactivité provient essentiellement des produits de fission, comme le montre la comparaison des niveaux d'activité dans les tableaux 16 et 17. Avec le temps, l'activité du combustible épuisé diminue, devenant à peu près 10 fois moindre après la première

La gestion des déchets radioactifs dans la partie aval du cycle du combustible est essentiellement une question de gestion du combustible nucléaire épuisé, en l'absence de retraitement de ce combustible. Des quantités relati- vement faibles de matières radioactives sont produites d'autres façons, et ces matières sont appelées déchets de réacteur. Par exemple, une certaine quantité du deutérium contenu dans l'eau lourde absorbe des neutrons et est convertie en tritium radioactif; des filtres à eau éliminent de petites quantités de produits de corrosion radioactifs; et des vêtements jetables peuvent renfermer de faibles quantités de matières radioactives.

Le combustible irradié est fortement radioactif, et les éléments combustibles épuisés contiennent plus de 100 radionucléides qui ont été produits pendant le fonctionnement du réacteur. Ces radionucléides se répartissent en deux groupes. La première catégorie comprend les **produits de fission** provenant de la fission d'un atome lourd en deux atomes légers. Cette fission ne se produit pas toujours de la même façon, de sorte qu'une série de produits de fission est produite dans le combustible. Certains de ce nouveau éléments sont stables mais les autres se désintègrent eux-mêmes à l'intérieur de leur période caractéristique, formant parfois de nouveaux radionucléides. Les produits de fission ont tendance à être de puissants émetteurs bêta et gamma, et la majorité ont des périodes relativement courtes.

Le deuxième groupe de radionucléides contenus dans le combustible épuisé inclut les **actinides**. Les actinides constituent une série d'éléments de numéro atomique égal ou supérieur à 89, qui possèdent des propriétés chimiques semblables. L'uranium et le plutonium sont les éléments les mieux connus de ce groupe. Dans un réacteur CANDU, l'uranium 235 absorbe un neutron par fission pour entretenir la réaction en chaîne. L'autre 1,5 neutron produit en moyenne par fission est absorbé par d'autres matières, principalement l'uranium 238. Les actinides sont produits par une série de réactions d'absorption de neutrons et de désintégrations radioactives. Ils ont tendance à être des émetteurs alpha, et un grand nombre d'entre eux ont de longues périodes.

Le tableau 15 donne la composition d'un faisceau de combustible CANDU avant et après irradiation dans un réacteur, avec une période de refroidissement de six mois. Les quantités sont exprimées en grammes et les constituants totalisent 19 kilogrammes. Le calcul suppose un épuisement du combustible de 6500 gigajoules par kilogramme d'uranium. Le tableau 16 est une liste de certains des produits de fission importants qu'on retrouve dans le combustible épuisé CANDU. Les actinides les plus importants présents dans le combustible épuisé CANDU sont indiqués au tableau 17. Les deux tableaux donnent les niveaux d'activité au moment du rejet, après un an et après 10 ans. Parmi les produits de fission, le technétium 99, l'iode 129 et le césium 135 présentent le plus grand danger à long terme. Parmi les actinides, le plutonium 239 et le plutonium 240 sont les plus dangereux à long terme.

Tableau 14 : Production de déchets dans le cycle du combustible CANDU par faisceau de combustible

Quantité de déchets produite par un faisceau de combustible CANDU, qui produit 33,6 millions de kWh d'électricité, suffisamment pour fournir l'énergie nécessaire pour la cuisine, le chauffage, etc. dans un foyer canadien moyen pendant plus de 100 ans.

	Quantité		**Radioactivité totale** (1)	
	Minerai de l'Ont.	***Minerai de la Sask.***	***Minerai de l'Ont.***	***Minerai de la Sask.***
Extraction (stérile)	20 tonnes	10 tonnes	0,0008 Curie	0,008 Curie
Concentration (résidus de concentration)	20 tonnes	1 tonne	0,0713 Curie	0,0648 Curie
Raffinage (raffinat – recyclé)	(8 kilogrammes) (2)		0,00004 Curie	
Conversion (nitrate d'ammonium – vendu comme engrais)	(20 kilogrammes) (2)		Fond	
Centrales				
• **Déchets de faible radioactivité** (3)	0,43 mètre cube		1,7 Curies	
• **Combustible épuisé** (4)	20 kilogrammes ($0,005\ m^3$)		16 000 Curies	

1) Un Curie (Ci) est pratiquement égal à la quantité de radioactivité dans un gramme de radium 226.

2) Les déchets du raffinage et les déchets de la conversion sont entièrement recyclés.

3) Moyenne pour l'Ontario Hydro, 1986 et 1987, à la réception. Après traitement, le volume a été réduit à une moyenne de 0,29 mètre cube.

4) En supposant un épuisement de 7 500 MW-jours par tonne. L'activité spécifiée est celle observée un an après rejet du réacteur.

Source : Communication personnelle : Eva Rossinger, Établissement de recherches nucléaires de Whiteshell, ÉACL, Pinawa (Manitoba), 4 juillet 1988.

les réacteurs de puissance canadiens. Ces faisceaux de combustible épuisé fortement radioactifs contiennent une série de nouveaux radionucléides. Leur gestion sûre est une composante essentielle du programme canadien d'énergie nucléaire.

Le tableau 14, fourni par l'Établissement de recherches nucléaires de Whiteshell de l'ÉACL, résume la production de déchets dans le cycle du combustible CANDU complet. Les quantités de déchets correspondent à la production et à l'utilisation d'un faisceau de combustible CANDU, avec un épuisement de combustible estimé à 7500 mégawatts-jours par tonne d'uranium. Les niveaux de réactivité du combustible irradié correspondent aux niveaux observés un an après rejet du réacteur. Aux étapes de l'extraction minière et de la concentration, les valeurs sont données pour le minerai d'uranium de l'Ontario et pour le minerai plus riche de la Saskatchewan. Le volume de déchets produit est le plus grand aux étapes de l'extraction et de la concentration de l'uranium. La gestion des déchets à ces étapes dépend du niveau de radioactivité par unité de volume des déchets. Les résidus de concentration dans les mines de l'Ontario sont stockées à l'air libre, ceux de la Saskatchewan sont stockés dans des silos de béton.

Les déchets radioactifs de faible activité produits par les centrales nucléaires sont placés dans des tranchées de terre, des trous gainés de tuile ou des silos de béton. C'est, de loin, le combustible irradié qui est le plus radioactif. Le combustible épuisé est stocké dans des piscines garnies de béton et remplies d'eau ou dans des contenants en béton secs refroidis à l'air. Les contenants en béton sont utilisés pour stocker le combustible épuisé provenant du déclassement des centrales de Douglas Point, Gentilly 1 et NPD. Le Canada n'a pas encore établi de méthode d'évacuation finale des déchets hautement radioactifs, mais il concentre son programme de recherche sur l'enfouissement profond en formations géologiques stables. Le principe adopté est d'isoler les déchets hautement radioactifs jusqu'à ce que les dangers radiologiques aient atteint un niveau acceptable et de gérer ces déchets de façon que les générations futures n'héritent pas du fardeau de la gestion ou de la surveillance des déchets.

Un autre aspect du problème de la gestion des déchets est associé au déclassement des réacteurs nucléaires et des autres installations nucléaires.

B. Gestion des déchets fortement radioactifs

Dans son étude sur la gestion des déchets radioactifs, le Comité a concentré ses efforts sur la partie aval du cycle du combustible nucléaire. Cet examen a été étendu aux pays visités par le Comité et plus particulièrement à la Suède, dont le programme de gestion des déchets comporte plusieurs parallèles avec le programme canadien.

pour le fluorure de calcium qui est enfoui dans un site de gestion des déchets, mais ses possibilités comme agent fondant dans la production d'acier sont à l'étude. Au Canada, cette branche du cycle du combustible nucléaire ne produit aucun autre déchet puisque les usines d'enrichissement sont situées dans des pays étrangers (Canada, ÉACL, 1984).

L'uranium utilisé dans les réacteurs CANDU, soit 20 % environ de notre production d'uranium, est converti en dioxyde d'uranium (UO_2), processus qui produit du nitrate d'ammonium comme résidu. Le nitrate d'ammonium est très peu radioactif et est vendu comme engrais liquide commercial aux agriculteurs locaux (Lyon et Tutiah, 1984).

Les Ressources Eldorado peuvent aussi produire à Port Hope de l'uranium métallique et des alliages d'uranium, ainsi que du diuranate d'ammonium, à partir d'uranium épuisé.

Le dioxyde d'uranium destiné aux réacteurs CANDU est transformé par frittage en pastilles, puis en faisceaux de combustible. Des quantités négligeables de déchets sont produits lors de la fabrication du combustible. Le nom des sociétés qui détenaient un permis de la CCÉA le 31 mars 1988 pour fabriquer du combustible au Canada, ainsi que le lieu et la capacité de leurs installations, sont (Canada, CCÉA, 1988, p. 20) :

. La Générale Électrique du Canada Inc. :
Toronto (Ontario) — 1 050 tonnes d'uranium par an sous forme de pastilles de combustible
Peterborough (Ontario) — 1 000 tonnes d'uranium par an sous forme de pastilles de combustible

. Zircatec Precision Industries Inc. :
Port Hope (Ontario) — 900 tonnes d'uranium par an sous forme de pastilles et de faisceaux de combustible

. Earth Sciences Extraction Co. :
Calgary (Alberta) — 70 tonnes de composés à base d'oxyde d'uranium par an

Un réacteur en fonctionnement rejette dans l'environnement de petites quantités de matières radioactives à même ses effluents liquides et aériens. Ces rejets sont contrôlés et limités conformément aux règlements de la CCÉA. Les rejets d'un réacteur qui fonctionne normalement représentent une très faible fraction des rayonnements naturels auxquels tous les Canadiens sont exposés.

L'exploitation et l'entretien d'un réacteur produisent aussi d'autres types de déchets radioactifs. Plus de 99 % de toute la radioactivité associée à la partie aval du cycle du combustible nucléaire provient du combustible irradié après utilisation dans

raffinat est recyclé dans une des deux usines de concentration d'uranium à Elliot Lake (voir le tableau 13) dans le but d'en extraire davantage d'uranium. Les constituants résiduels du raffinat sont rejetés à même les résidus de concentration (Canada, ÉACL, 1984; Canada, CCÉA, 1988).

Tableau 13 : Installations canadiennes d'extraction et de concentration de l'uranium pour lesquelles des permis ont été délivrés par la CCÉA

Installation et lieu	Détenteur de permis	Capacité
Cluff Lake, Phase II (Saskatchewan)	Amok Ltd.	1 000 tonnes d'uranium/an
Collins Bay B-Zone, Eldor Mines (Saskatchewan)	Eldorado Resources Ltd.	3 200 tonnes d'uranium/an
Denison Mines, Elliot Lake (Ontario)	Denison Mines Ltd.	10 900 tonnes à concentrer/jour 4 000 tonnes de raffinat acide/an 900 tonnes de raffinat chaulé/an
Key Lake (Saskatchewan)	Key Lake Mining Corp.	5 700 tonnes d'uranium/an
Panel Mine, Elliot Lake (Ontario)	Rio Algom Ltd.	3 000 tonnes d'uranium/jour
Quirke Mine, Elliot Lake (Ontario)	Rio Algom Ltd.	6 350 tonnes à concentrer/jour 5 000 tonnes de raffinat acide/an
Stanleigh Mine, Elliot Lake (Ontario)	Rio Algom Ltd.	6 000 tonnes à concentrer/jour
Stanrock Mine, Elliot Lake (Ontario)	Denison Mines Ltd.	3 800 tonnes de minerai/jour

Source : Canada, CCÉA, *Rapport annuel 1987-1988*, Ottawa, 1988, p. 18.

Le trioxide d'uranium produit à Blind River est transformé en l'un ou l'autre de deux produits, selon que l'uranium est destiné à devenir du combustible CANDU ou selon qu'il sera vendu à l'étranger pour être enrichi et servir de combustible dans des réacteurs à eau légère. Les deux types de conversion sont effectuées par Les Ressources Eldorado dans des usines de conversion situées à Port Hope (Ontario). La plus grande partie de l'uranium produit au Canada est destiné à l'exportation. Cet uranium est converti en hexafluorure d'uranium (UF_6), dans une étape préparatoire à l'enrichissement, et est exporté sous cette forme. Le principal résidu de ce processus de conversion est le fluorure de calcium. On n'a actuellement trouvé aucune utilisation

concentrations d'uranium jugées exploitables sont appelées «corps minéralisés». Dans toute exploitation d'uranium, des quantités substantielles de roches stériles sont extraites en même temps que le minerai d'uranium. La roche stérile contient certaines matières radioactives, mais sa teneur en uranium est trop faible pour en justifier le traitement. Les déchets miniers sont entreposés en surface à proximité de la mine, et la pratique la plus répandue consiste à recouvrir la roche stérile de terre et de végétation (Lyon et Tutiah, 1984).

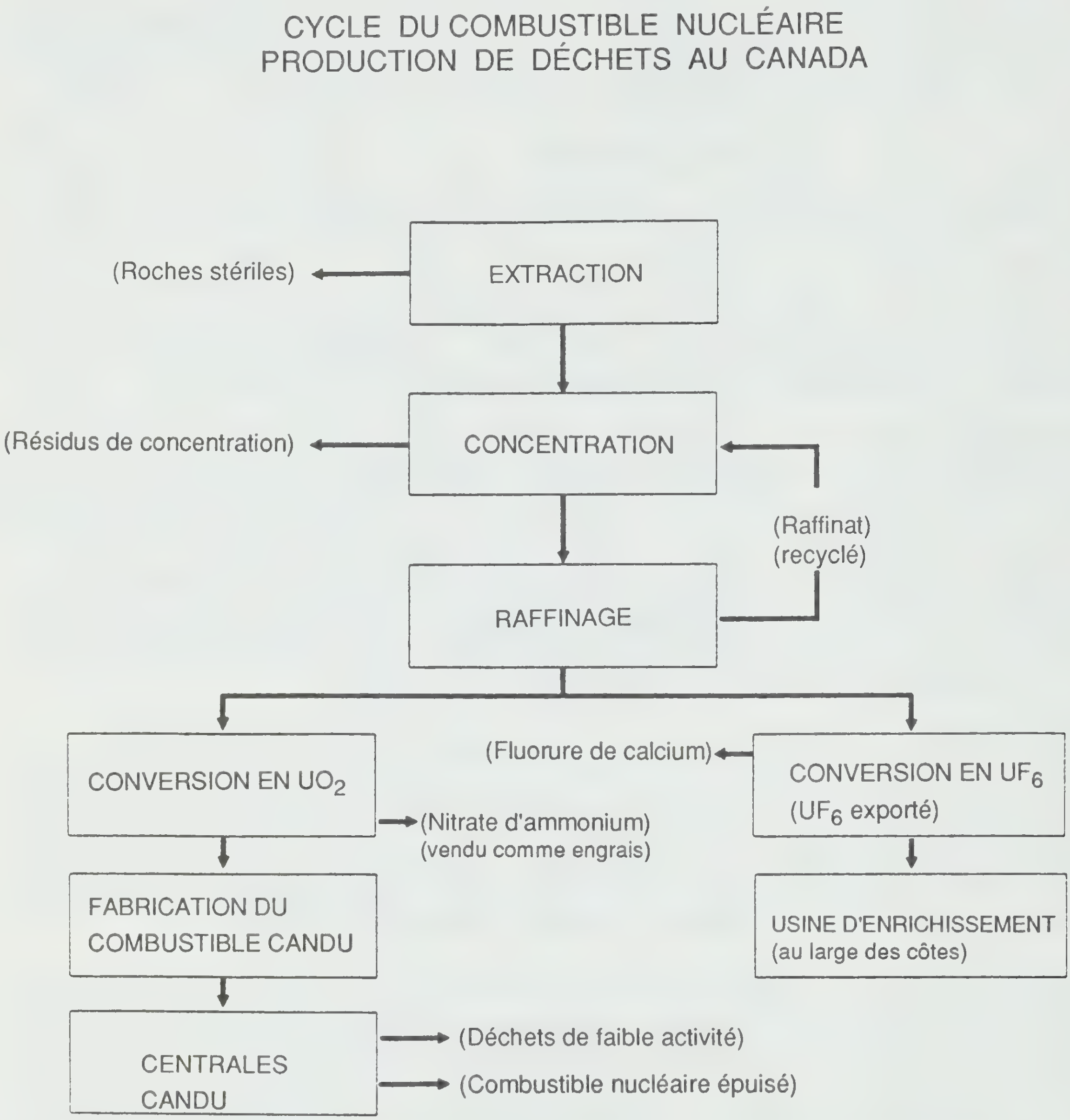
Le minerai d'uranium est transporté vers une usine de concentration, habituellement située près de la mine, où l'uranium est séparé de la roche stérile résiduelle. Le minerai est broyé en un sable fin auquel des produits chimiques sont ajoutés pour en dissoudre l'uranium. Le liquide contenant l'uranium dissous est ensuite soumis à un traitement chimique pour en extraire l'uranium; le concentré résultant est filtré et séché en un produit appelé «yellowcake», qui est un concentré d'uranium. Les déchets ou «résidus» de concentration comprennent la roche stérile finement broyée et les matières radioactives autres que l'uranium. Ces déchets sont rejetés de l'usine de concentration sous la forme d'une boue et sont en général stockés dans des bassins à résidus (Lyon et Tutiah, 1984). Les résidus de concentration de certaines mines de la Saskatchewan sont toutefois plus radioactifs et sont stockés dans des enceintes de béton.

Une bonne gestion des résidus de concentration est importante. Les résidus contiennent non seulement des matières radioactives provenant de la chaîne de désintégration de l'uranium, mais aussi des éléments toxiques tels que de l'arsenic et du sélénium qui sont présents dans le corps minéralisé. Les bassins à résidus devraient être conçus de façon à empêcher tout liquide contaminé de fuir dans le réseau des eaux souterraines et dans les cours d'eau de surface, et la quantité de radon gazeux qui s'échappe dans l'atmosphère devrait être contrôlée. Malheureusement, les résidus d'extraction et de concentration de l'uranium ne sont pas toujours bien gérés au Canada.

Le tableau 13 est une liste des installations d'extraction et de concentration de l'uranium qui détenaient des permis de la CCÉA le 31 mars 1988. Toutes les installations d'extraction et de concentration de l'uranium au Canada sont actuellement situées en Ontario et en Saskatchewan. Le tableau 13 ne couvre pas les permis que la CCÉA a délivrés pour le «prélèvement de minerai» ou l'«exploration souterraine», permis autorisant des sociétés à extraire des quantités limitées de minerai d'uranium à des fins d'essais ou à d'autres fins non commerciales.

Le concentré d'uranium est transporté depuis les diverses usines de concentration vers la seule raffinerie d'uranium canadienne qui soit exploitée par Ressources Eldorado Ltée à Blind River (Ontario). Cette raffinerie peut produire 18 000 tonnes de trioxide d'uranium (UO_3) par année. Les déchets de raffinage sont appelés raffinat et contiennent des matières radioactives indésirables ainsi qu'un peu d'uranium utile. Le

Graphique 14 : Le cycle du combustible nucléaire au Canada et ses déchets associés



Source : Communication personnelle : Eva Rossinger, Établissement de recherches nucléaires de Whiteshell, ÉACL, Pinawa (Manitoba), 4 juillet 1988.

LA GESTION DES DÉCHETS RADIOACTIFS AU CANADA

A. Le cycle du combustible nucléaire au Canada

Des déchets radioactifs sont produits à chaque étape du cycle du combustible nucléaire, depuis l'extraction de l'uranium jusqu'au retrait du combustible nucléaire irradié d'un réacteur (et au retraitement du combustible dans certains pays autres que le Canada). Dans un examen plus approfondi, ce cycle peut être subdivisé en trois étapes.

1) La première étape comprend l'extraction et la concentration du minerai d'uranium, suivi du raffinage de l'uranium et de sa transformation en éléments combustibles. Cette séquence d'opérations est souvent appelée la partie amont du cycle du combustible.

2) La deuxième étape est l'exploitation de réacteurs nucléaires pour la production d'électricité, laquelle donne lieu à des rejets de faible radioactivité dans les effluents de la centrale pendant le fonctionnement normal du réacteur.

3) La troisième étape est la gestion du combustible épuisé et des déchets du réacteur. Cette étape comprend le stockage temporaire et l'élimination finale des déchets radioactifs, et elle est souvent qualifiée de partie aval du cycle du combustible nucléaire. Lorsque le cycle du combustible est fermé et que le combustible épuisé est retraité, cette partie comprend le retraitement du combustible épuisé et l'élimination des déchets de retraitement. Lorsque le cycle du combustible est ouvert, c'est-à-dire que le combustible n'est utilisé qu'une fois, le cycle se termine par l'élimination du combustible épuisé.

Le graphique 14 illustre le cycle du combustible nucléaire au Canada et les différentes étapes pendant lesquelles des déchets sont produits. Le cycle du combustible canadien comprend deux parties. Dans la première, l'uranium naturel est transformé en oxyde d'uranium combustible qui est utilisé dans les réacteurs CANDU. Dans l'autre, l'uranium est converti en hexafluorure d'uranium gazeux, puis exporté vers des clients qui ont besoin de combustible enrichi pour exploiter des réacteurs à eau légère.

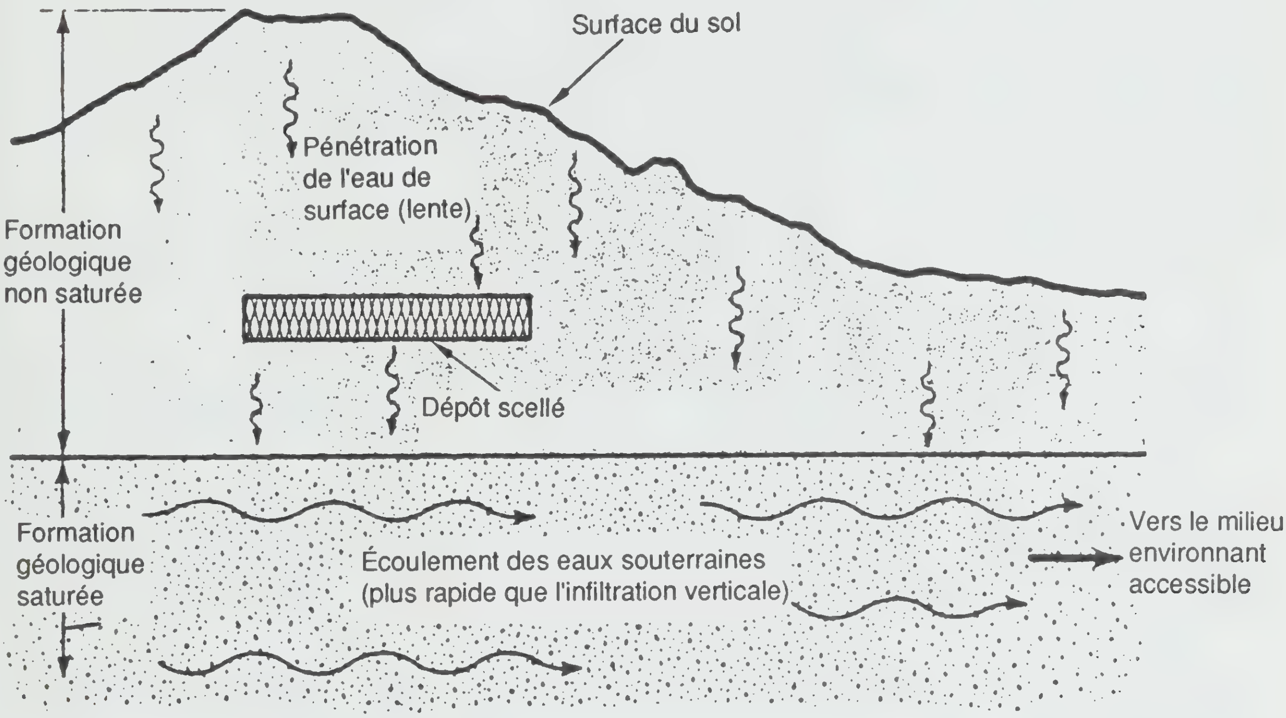
L'uranium est un des éléments lourds les plus abondants dans la croûte terrestre. Il est naturellement radioactif; l'uranium et ses produits de désintégration se retrouvent dans la roche, le sol, les eaux de surface et souterraines, et les océans. Le radon gazeux radioactif, qui est un des produits de désintégration ou de «filiation» de l'uranium, constitue un danger bien reconnu dans l'exploitation de l'uranium et a été plus récemment reconnu comme un danger possible dans certains foyers canadiens. Les

Taux de stockage	Phase 1 (2003) : 400 tonnes/année Phase 2 (2008) : 3000 tonnes/année
Confinement de la radioactivité	10 000 ans
Confinement de l'emballage des déchets	Assez complet pour 300 à 1000 ans
Temps de déplacement de l'eau souterraine	1000 ans jusqu'à l'environnement accessible
Taux de rejet des radionucléides (après 1000 ans)	1 partie sur 100 000 par année

On prévoit que le stockage des déchets au site du mont Yucca durera 26 ans, après quoi le dépôt sera rempli. Après la période de stockage, une période de «surveillance» de 24 ans commencera. Pendant cette période totale de 50 ans, au cours de laquelle différents essais seront effectués en vue de s'assurer que le dépôt satisfait aux critères prévus, les déchets seront récupérables. À la fin de la période de surveillance, le dépôt sera scellé de façon permanente. Les installations en surface seront décontaminées et déclassées, et le site sera remis à son état naturel, dans la mesure du possible. Des repères de site seront érigés afin d'indiquer aux générations futures la présence d'un dépôt (États-Unis, DOE, *Office of Civilian Radioactive Waste Management*, 1988, p. 33).

Si les études de caractérisation révèlent que le mont Yucca n'est pas un site convenable pour un dépôt de déchets hautement radioactifs, on déclassera les installations exploratoires et on déterminera un nouveau site.

Graphique 13 : Coupe schématique du site proposé au mont Yucca



Source: États-Unis, DOE, Office of Civilian Radioactive Waste Management, *Site Characterization Plan – Overview: Yucca Mountain Site, Nevada Research and Development Area, Nevada. Consultation Draft*, DOE/RW–0161, Washington, D.C., janvier 1988, p. 41.

Principaux paramètres	Exigence/critère
Types de déchets acceptés	Combustible épuisé, déchets de retraitement vitrifiés et déchets militaires hautement radioactifs.
Capacité	70 000 tonnes de déchets

Le calendrier actuel de mise en place du premier dépôt dans des formations géologiques comprend les objectifs suivants (Kay, 1988, p. 8) :

. Début de la construction du puits d'exploration	2e trimestre 1989
. Début des essais *in situ*	4e trimestre 1990
. Présentation du rapport de choix du site et de l'énoncé des incidences environnementales au Président	1994
. Présentation de la demande d'autorisation à la NRC	1995
. Réception de l'autorisation de construction de la NRC	1998
. Début de la construction	1998
. Début des opérations de la phase 1	2003
. Début des opérations de la phase 2	2006

Le processus de délivrance de permis pour le site et d'autorisation comporte quatre étapes : caractérisation, autorisation de construction, délivrance de permis pour le dépôt et déclassement du dépôt. Des rapports doivent être présentés à la NRC et aux organismes fédéraux et d'État à chaque étape; ces documents sont rendus publics. Le site doit satisfaire à une exigence de confinement des déchets pendant 10 000 ans établie par l'EPA. Le mont Yucca est situé dans une région aride du sud-ouest des États-Unis. Le dépôt serait construit au-dessus de la nappe phréatique dans une zone rocheuse où existe un écoulement très lent d'eau souterraine vers le bas, comme le montre schématiquement le graphique 13.

Le mont Yucca est situé dans le sud du Nevada à la limite ouest du site d'essai du Nevada, à environ 100 milles de Las Vegas. Le site chevauche la jonction de trois blocs de terre fédérale. La plus grande partie du dépôt et les installations connexes en surface seraient à l'intérieur du champ de tir Nellis de l'armée de l'air, et de plus petites parties seraient comprises à l'intérieur du site d'essai du Nevada et sur des terrains gérés par le *Bureau of Land Management*.

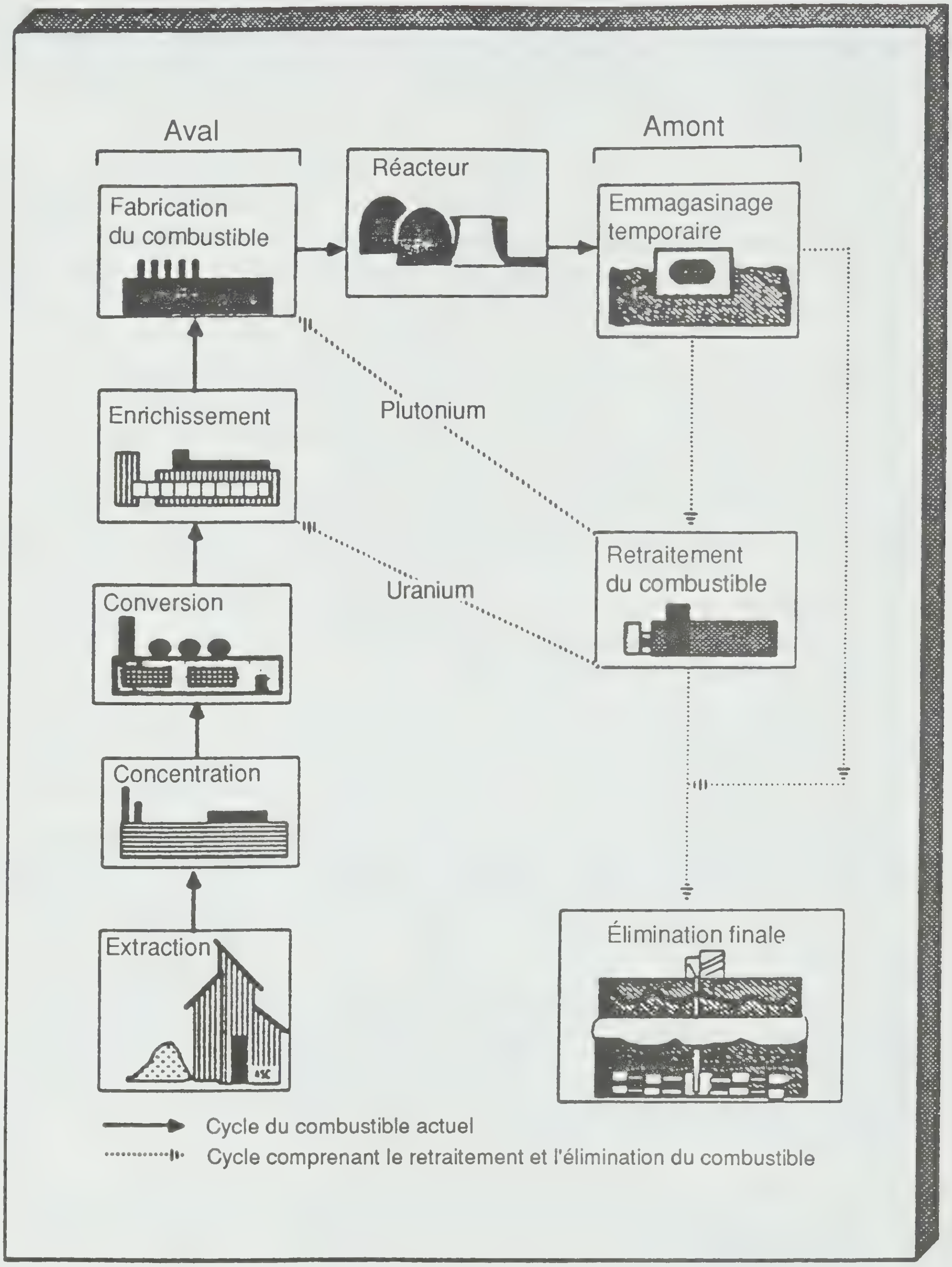
La roche du dépôt est un tuf soudé, les restes solidifiés d'une coulée de cendres volcaniques chaudes produite au cours d'une période de volcanisme qui a commencé il y a 16 millions d'années et s'est terminée il y a 8 millions d'années environ. La coulée de roches volcaniques a environ 6 500 pieds d'épaisseur au site. Les principaux critères de conception pour un dépôt dans des formations géologiques exploitées sont énumérés dans la liste qui suit. (Communication personnelle : Jerome Saltzman, *Office of Civilian Radioactive Waste Management*, DOE, Washington, D.C., 1er mai 1988.)

Deux organismes fédéraux ont la tâche de déterminer les exigences de la réglementation applicable à l'évacuation des déchets hautement radioactifs. La *Nuclear Regulatory Commission* est le principal organisme chargé du choix du site du dépôt, de sa construction, de son exploitation et de son déclassement. Elle délivrera les permis relatifs au dépôt et définira ses critères techniques. L'*Environmental Protection Agency*, (EPA) est chargée d'élaborer, pour les dépôts, des normes visant à protéger la santé et à assurer la sécurité de la population.

La NWPA exige que les utilisateurs d'énergie électronucléaire paient le coût de l'évacuation du combustible nucléaire épuisé. Le gouvernement fédéral perçoit des droits de 1 millième de dollar par kilowattheure (0,1 ¢/kWh) des entreprises de services publics qui exploitent des centrales nucléaires. L'argent perçu est accumulé dans le *Nuclear Waste Fund* et sert à payer tous les éléments du programme d'évacuation des déchets : le dépôt, toute construction d'installations de SSR, le transport des déchets et l'aide fédérale à la participation des États et des tribus indiennes. On revoit annuellement l'état du fonds afin de s'assurer que des sommes suffisantes y sont accumulées pour couvrir le coût complet du système d'évacuation. Au 31 janvier 1988, le solde du fonds s'élevait à 1967,6 millions de dollars US. Le gouvernement fédéral paiera pour les déchets militaires qui seront placés dans le dépôt.

La NWPA exige que le DOE construise et exploite un dépôt et se charge des activités reliées au choix du site d'un deuxième dépôt. Jusqu'à récemment, les études de sites pour le premier dépôt portaient sur trois types de formation géologique : dômes de sel et dépôts de sel stratifiés dans le comté de Deaf Smith au Texas, basalte au site Hanford dans l'état de Washington, et tuf volcanique (cendres volcaniques solidifiées) au mont Yucca dans le Nevada. Dans des amendements récents apportés par le Congrès à la NWPA, le choix du site a été limité au mont Yucca, malgré les objections des représentants du Nevada, sous réserve des études de confirmation. Les amendements de la NWPA statuent que les travaux aux sites Hanford et Deaf Smith doivent être abandonnés graduellement dans les 90 jours, à l'exception des travaux de récupération. La disposition de la NWPA relative au choix du site d'un deuxième dépôt dans des formations géologiques a été abrogée et remplacée par une disposition stipulant que le DOE doit faire rapport au Président et au Congrès entre 2007 et 2010 sur la nécessité d'un deuxième dépôt. L'autorisation de choisir un site de stockage surveillé avec possibilité de reprise (SSR), de construire les installations et de les exploiter a été donnée dans les amendements. Par la même occasion, les amendements ont annulé la proposition du Secrétaire à l'énergie visant à construire une installation de SSR sur le site de l'ancien réacteur Clinch River à Oak Ridge (Tennessee). Les amendements statuent que dans le choix d'un site de SSR «le Secrétaire ne doit montrer aucune préférence pour les sites qui ont été choisis antérieurement».

Graphique 12 : Cycle du combustible nucléaire américain



Source: États-Unis, DOE, EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, *World Nuclear Fuel Cycle Requirements 1987*, DOE/EIA–0436(87), Washington, D.C., 27 août 1987, p. 2.

3. Gestion des déchets radioactifs

Le graphique 12 montre le cycle du combustible nucléaire américain. Les flèches en traits continus représentent le cycle du combustible actuel sans retraitement commercial et sans installation d'élimination des déchets; les flèches en traits pointillés montrent ce que serait le cycle du combustible si les États-Unis optaient pour le retraitement du combustible épuisé et l'évacuation des déchets.

La NRC classe les substances radioactives résultant du cycle du combustible nucléaire en deux catégories. Les **effluents** sont les substances rejetées dans l'environnement sous forme de gaz ou de liquides. Le contenu radioactif de ces effluents doit être inférieur aux limites imposées par la NRC et l'*Environmental Protection Agency*, et être aussi bas qu'il soit raisonnablement possible de le faire. Les **déchets** sont les substances qui présentent un risque radiologique assez élevé pour que des mesures particulières soient requises. Les déchets sont à leur tour subdivisés par la NRC en «déchets hautement radioactifs» et «déchets non hautement radioactifs». Les déchets hautement radioactifs comprennent le combustible irradié et les déchets de retraitement. Comme aucun retraitement commercial n'est effectué présentement aux États-Unis, presque tous les déchets hautement radioactifs du programme nucléaire sont contenus dans le combustible épuisé. Les déchets faiblement radioactifs ont normalement été enfouis dans des tranchées près de la surface, dans leurs contenants d'expédition, sans qu'il soit prévu de les récupérer. Il y avait auparavant six cimetières radioactifs commerciaux aux États-Unis mais au moins quelques-uns de ces cimetières ont cessé d'accepter des déchets (États-Unis, NRC, 1983).

La *Nuclear Waste Policy Act* (NWPA) de 1982 a établi une ligne de conduite nationale concernant l'évacuation des déchets hautement radioactifs. En vertu de cette loi, le DOE est chargé de l'évacuation sûre et permanente de ces déchets nucléaires.

> En vertu de la NWPA, le DOE doit choisir le site d'un dépôt dans des formations géologiques, délivrer les permis qui s'y rattachent, en assurer la construction et l'exploitation; choisir le site d'un deuxième dépôt; et être prêt à recevoir des déchets en vue de leur évacuation à compter du 31 janvier 1998. Il doit aussi réaliser une étude détaillée sur les besoins en matière de stockage surveillé avec possibilité de reprise (SSR) et sur la faisabilité d'un tel projet, et présenter une proposition au Congrès en vue de la construction d'une ou de plusieurs installations de SSR. De plus, la NWPA a établi un calendrier et un plan étape par étape pour la mise en oeuvre du système d'évacuation. Le Président, le Congrès, les États et les tribus indiennes touchés, le DOE et d'autres organismes fédéraux doivent travailler en collaboration en vue de la mise en oeuvre du système. Cette loi a prévu un mandat et un plan pour l'identification et le choix des sites des dépôts et pour la mise en oeuvre d'un système global de gestion des déchets (États-Unis, DOE, 1987a, p.6).

La loi a créé l'*Office of Civilian Radioactive Waste Management* au sein du DOE et l'a chargé de faire appliquer la loi, de faire respecter ses lignes de conduite et de gérer le programme national.

réacteur jusqu'au règlement complet des dommages causés par un accident. La figure 10 indique que les frais d'exploitation non liés au combustible avaient déjà atteint 95 dollars US par kilowatt de puissance installée (en dollars constants de 1982) en 1984; une hausse des frais d'exploitation de 10 millions de dollars US par réacteur (en dollars de 1988) ne représenterait pas une augmentation importante et pourrait être absorbée par les consommateurs sous la forme d'une hausse de tarifs. Les critiques veulent aussi que les fournisseurs et les entrepreneurs soient tenus responsables dans une certaine mesure. Un service public peut poursuivre un founisseur pour dommages, — comme l'a fait GPU Nuclear Corp. (consortium composé de *Metropolitan Edison*, de *Jersey Central Power and Light* et de *Pennsylvania Electric*) à l'endroit du fabricant de réacteurs, *Babcock & Wilcox*, pour des dommages causés sur place à la centrale de Three Mile Island — mais le fournisseur n'est pas tenu de détenir une assurance-responsabilité ni d'indemniser des particuliers.

Certains services publics des États-Unis n'ont pas réussi à réaliser un degré acceptable d'engagement en matière d'exploitation des centrales nucléaires. À la suite de l'accident de Three Mile Island, l'industrie nucléaire américaine a créé son *Institute of Nuclear Power Operations* (INPO), destiné à surveiller l'exploitation des centrales nucléaires des services publics. Certains résultats obtenus par l'INPO sont très inquiétants. Par exemple, l'INPO signale qu'à la centrale nucléaire Peach Bottom en Pennsylvanie les opérateurs du réacteur dormaient, s'amusaient à des jeux vidéo ou étaient distraits de quelque autre façon pendant qu'ils étaient de service dans la salle de commande. Le 31 mars 1987, la *Nuclear Regulatory Commission* a ordonné la fermeture de la centrale Peach Bottom à la suite de rapports indiquant que des opérateurs dormaient à leur poste. Dans un échange avec la gestion de l'entreprise de services publics, l'INPO a décrit son mécontentement dans les termes suivants :

> [...] le manque flagrant de professionnalisme d'une vaste gamme d'employés de quart (à tous les quarts) que les superviseurs ont toléré est le reflet d'une défaillance importante dans la gestion d'une installation nucléaire. Un tel comportement place l'industrie et la nation dans une situation très embarrassante.

D'autres entreprises de services publics, comme la Duke Power, dont le siège est en Caroline du Nord, ont apporté une importante contribution au nucléaire et elles mènent des programmes qui connaissent du succès. En général, cependant, les entreprises américaines n'ont pas atteint les facteurs de charge pour la durée de vie que de nombreuses entreprises européennes et japonaises, et l'Ontario Hydro, ont atteint.

L'industrie nucléaire américaine est à un point tournant. À défaut d'un rajeunissement important, elle pourrait languir au cours des années à venir.

Price-Anderson, la responsabilité maximale par accident est fixée à 700 millions de dollars US environ. En vertu des projets de modification de la loi que le Congrès entend introduire, il semble généralement convenu que l'assurance-responsabilité sera portée à environ 7 milliards de dollars US. Dans la version de la loi proposée par la Chambre des représentants, chaque exploitant d'un réacteur de puissance deviendrait responsable des dommages jusqu'à concurrence de 63 millions de dollars US par réacteur par accident, montant payable à un fonds d'indemnisation, à raison de 10 millions de dollars US par année. La première tranche d'assurance serait maintenue à 160 millions de dollars US. Dans la version du Sénat, à chaque réacteur serait associée une responsabilité allant jusqu'à 12 millions de dollars US par année pendant un maximum de cinq ans, ce qui donne une protection maximale d'environ 6,6 milliards de dollars US avec le nombre actuel de réacteurs autorisés. Les deux projets de modification prévoient une correction pour tenir compte de l'inflation. Aucun des deux projets n'étendrait la responsabilité aux fabricants des réacteurs ou aux autres fournisseurs, même lorsque le fournisseur est coupable de négligence ou de violation préméditée des règlements fédéraux en matière de sûreté. Une partie du débat porte sur la question de savoir si la Price-Anderson Act devrait être renouvelée pour 10 ans (version de la Chambre) ou pour 20 ans (version du Sénat) (Price-Anderson Campaign, «Briefing Packet»). Il y a tout lieu de croire que la Chambre et le Sénat s'entendront pour la reconduire sur 15 ans.

En août 1988, la Chambre et le Sénat sont arrivés à un compromis au sujet du renouvellement de la loi Price-Anderson. La Loi fut prorogée pour 15 ans, jusqu'au 1er août 2002. Le plafond de responsabilité passa à environ 7 milliards de dollars US et s'applique maintenant aux détenteurs de permis de la NRC, et aux installations des entrepreneurs du DOE. Dans le cas des détenteurs de permis de la NRC, les dommages seront payés par le groupe d'assureurs décrit ci-dessus. Dans le cas d'un accident survenant dans une installation nucléaire d'un entrepreneur du DOE, le gouvernement fédéral paiera les dommages. Si les dommages consécutifs à un accident nucléaire dépassent les 7 milliards de dollars US, le Président doit soumettre au Congrès un plan de compensation incluant une estimation des dommages et des recommandations en ce qui concerne les sources de financement pour les dommages excédant la limite de reponsabilité. Dans une nouvelle orientation, la Loi permet au secrétaire de l'Énergie d'imposer des amendes pouvant atteindre 100 000 dollars US par jour aux entrepreneurs qui enfreignent les règlements du DOE en matière de sécurité. Les employés des entrepreneurs sont passibles de poursuites judiciaires s'ils enfreignent délibérément les règles de sécurité. Ces poursuites civiles ne s'appliquent pas aux laboratoires de recherche nucléaire du DOE (tels Los Alamos, Lawrence Livermore, Sandia et Brookhaven).

Les critiques de la loi Price-Anderson font remarquer que la NRC a proposé au Congrès, en 1983, de ne pas limiter la responsabilité des services publics : tout exploitant serait alors tenu de payer des montants annuels de 10 millions de dollars US par

permis de possession et d'utilisation de matières radioactives; de réglementer le conditionnement des matières radioactives pour fins de transport; d'élaborer des lignes de conduite pour protéger les installations et les matières nucléaires contre le vol, le sabotage ou le détournement; et d'examiner l'application des mesures de sécurité de l'AIÉA relatives aux matières nucléaires de source américaine utilisées dans des pays étrangers. Ce bureau dirige aussi l'exécution des responsabilités de la Commission en vertu de la *Nuclear Waste Policy Act* de 1982, de la *Low-Level Radioactive Waste Policy Act* de 1980 et de la *Low-Level Radioactive Waste Policy Amendments Act* de 1985, qui régissent l'élimination des déchets faiblement radioactifs, et de la *Uranium Mill Tailings Radiation Control Act* de 1978.

L'*Office of Nuclear Regulatory Research* planifie et met en oeuvre des programmes de recherche en matière de réglementation nucléaire, élabore des étalons et résoud des questions de sûreté dans les installations réglementées; élabore et promulgue des règlements techniques; et coordonne les travaux de recherche au sein et à l'extérieur de la Commission.

Lorsqu'on a demandé au Comité pourquoi la NRC avait mis au point un système de réglementation des réacteurs de puissance aussi normatif, le directeur de la Commission, Harold Denton, a fait observer que les 109 réacteurs de puissance exploitables aux États-Unis s'inspiraient d'au moins 60 configurations distinctes. La normalisation n'a pas été un objectif des constructeurs de réacteurs commerciaux aux États-Unis.

La question de la responsabilité civile est traitée dans la *Price-Anderson Act* qui établit un système d'indemnisation privée et publique pour des dommages corporels et matériels causés par un accident nucléaire. Toute centrale nucléaire commerciale d'une puissance nominale de 100 MWe ou plus doit détenir une assurance-responsabilité civile. Une assurance fédérale limitée couvre les activités du DOE (la plupart étant liées à la défense). La loi a été adoptée en 1957 et a été reconduite deux fois pour des périodes de 10 ans. La première reconduction a pris fin le 31 juillet 1987, et le Congrès envisageait une deuxième reconduction au moment de la visite du Comité à Washington.

La loi Price-Anderson prévoit une assurance en deux tranches. Les premiers 160 millions de dollars US sont fournis par deux consortiums privés d'assureurs responsabilité nucléaire, *American Nuclear Insurers* et *Mutual Atomic Energy Liability Underwriters*. Si un accident devait causer plus de 160 millions de dollars US de dommages, «chaque exploitant d'une centrale nucléaire commerciale serait tenu responsable d'une part, établie au prorata, des dommages excédant la première tranche d'assurance, jusqu'à 5 millions de dollars par réacteur par année par incident, sans dépasser 10 millions de dollars pour chaque réacteur dans une même année» (États-Unis, NRC, 1983, p. 1). Ainsi en vertu de la présente version de la loi

La Nuclear Regulatory Commission (NRC) réglemente l'utilisation civile des matières nucléaires aux États-Unis. Créée par l'*Energy Reorganization Act* de 1974, la NRC a repris les fonctions de réglementation de l'ancienne Atomic Energy Commission. L'*Energy Research and Development Agency* (qui devait à son tour être intégrée au *Department of Energy*) assumait les autres fonctions de l'AEC. La NRC est chapeautée par cinq commissaires qui sont nommés par le Président pour des mandats de cinq ans, sous réserve de l'aval du Sénat. Avec ses 3 300 employés et un budget moyen de 400 millions de dollars US, la NRC dispose d'un personnel 12,5 fois supérieur et d'un budget plus de 19 fois supérieur à ceux de son homologue canadien, la Commission de contrôle de l'énergie atomique. Le programme nucléaire civil américain porte sur une capacité de production huit fois environ supérieure à celle visée par le programme canadien. À titre de comparaison, il serait plus intéressant de mentionner que la CCÉA compte deux avocats parmi ses effectifs, tandis que la NRC en compte environ 200.

La NRC assume trois fonctions fondamentales, en plus de délivrer les permis d'exportation et d'importation de matières et de matériel nucléaires :

1) La Commission émet les permis de construction et d'exploitation des centrales et autres installations nucléaires. Elle émet les permis de possession et d'utilisation de matières nucléaires à des fins médicales, industrielles, éducatives et de recherche. Le pouvoir de réglementation pour la délivrance de permis touchant des matières nucléaires a toutefois été transféré à 29 États en vertu de l'*Agreement States Programme* de la NRC.

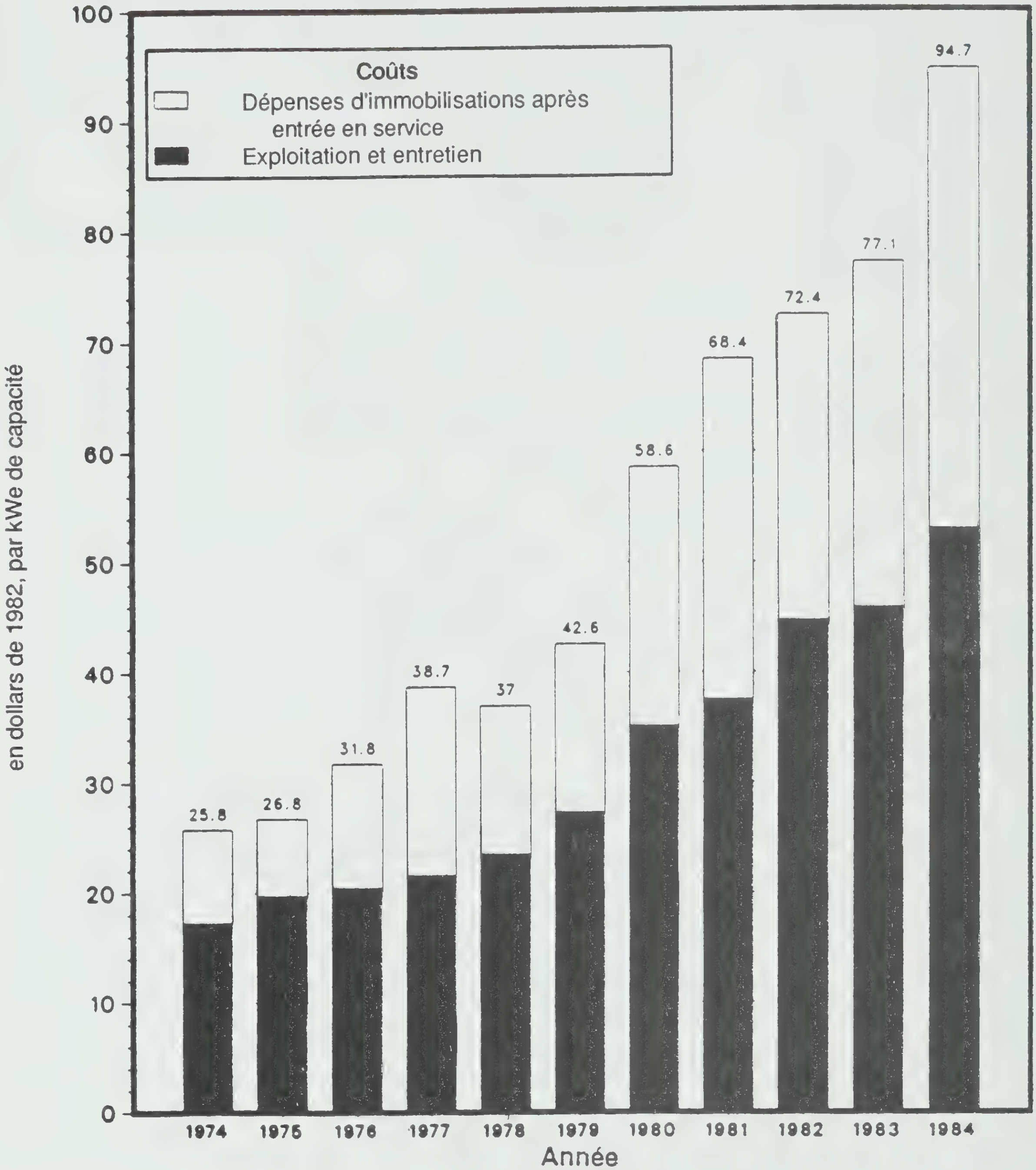
2) La Commission mène des inspections et des enquêtes pour s'assurer que toute activité autorisée par un permis s'effectue dans le respect des règlements, et elle veille à ce que les règlements soient appliqués.

3) La Commission est légalement mandatée pour mener un vaste programme de recherche en matière de réglementation dans les domaines de la sûreté, de la sécurité et de l'évaluation environnementale nucléaires. Depuis l'accident de Three Mile Island, la recherche en matière de réglementation a coûté en moyenne plus de 100 millions de dollars US par année (États-Unis, NRC, non daté).

Les opérations de la NRC sont réparties entre trois bureaux. L'*Office of Nuclear Reactor Regulation* évalue les demandes de construction et d'exploitation de réacteurs de puissance; effectue les inspections et délivre les permis de construction et d'exploitation des réacteurs de puissance; effectue les inspections et délivre les permis de construction et d'exploitation des réacteurs de recherche et d'essai; et délivre les permis aux exploitants de réacteurs.

L'*Office of Nuclear Material Safety and Safeguards* est chargé de délivrer les permis pour les installations liées au cycle du combustible nucléaire; de délivrer les

Graphique 11 : Hausse des frais d'exploitation réels annuels non liés au combustible des réacteurs américains d'une puissance minimale de 400 MW, 1974-1984



Source : États-Unis, DOE, EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, *An Analysis of Nuclear Power Plant Operating Costs*, DOE/EIA–0511, Washington, D.C., 16 mars 1988, p. viii.

maintenance des années antérieures, a pour effet de réduire les coûts des nouvelles immobilisations, en proportion inverse des frais de maintenance. L'effet de la réglementation étatique sur les coûts des immobilisations n'a pas pu être déterminé. (États-Unis, DOE, EIA, 1988)

Le vieillissement des installations a un double effet : l'expérience acquise tend à réduire les coûts, mais la détérioration des équipements tend à les faire augmenter. Pour ce qui est des frais d'exploitation et de maintenance, le premier facteur contrebalance le second. C'est toutefois le contraire qui se produit pour ce qui est du coût des immobilisations post-opérationnelles. L'étude ayant été restreinte aux réacteurs nucléaires d'une puissance minimale de 400 MW, l'âge moyen des centrales étudiées n'était que de huit ans. Le DOE a donc émis des réserves pour quiconque serait tenté de tirer des conclusions définitives de cette étude limitée quant aux tendances futures des frais d'exploitation et de maintenance en fonction du vieillissement des installations. (États-Unis, DOE, EIA, 1988)

Le graphique 11 fait état de la hausse des frais d'exploitation réels annuels non liés au combustible des réacteurs de puissance américains au cours de la période de 11 ans allant de 1974 à 1984. Les frais sont ventilés en immobilisations post-opérationnelles et en frais d'exploitation et de maintenance; ils sont exprimés en dollars constants de 1982.

L'EIA estime que les dépenses normales d'exploitation et d'entretien, mesurées en dollars 1982, sont passées de 17 $US le kilowatt de puissance électrique installée en 1974 à 53 $US le kilowatt en 1984. Cette hausse représente un accroissement annuel moyen de 12 %. Les investissements après exploitation sont passés de 9 $US par kilowatt à 42 $US, soit un accroissement annuel moyen de 17 %. Par contre, l'EIA indique que les coûts réels d'exploitation et d'entretien des centrales alimentées au charbon n'ont augmenté qu'à un rythme annuel de 2 % pendant la même période. Ces résultats ont amené l'EIA à tirer deux conclusions.

> [...] D'abord, la hausse continue des coûts d'exploitation peut réduire ou même annuler tout avantage sur le plan des coûts attribuables à l'énergie nucléaire. De nombreux analystes croient que les centrales nucléaires dont l'exploitation commerciale a débuté dans les années 1960 et 1970 étaient rentables par comparaison aux centrales alimentées au charbon. La situation peut changer si les coûts d'exploitation continuent d'augmenter. En deuxième lieu, bon nombre de promoteurs de l'énergie nucléaire supposent actuellement que la durée utile autorisée des centrales nucléaires sera supérieure à 40 ans. Si les coûts d'exploitation continuent d'augmenter, viendra peut-être un temps où il sera avantageux de fermer les anciennes centrales; c'est pourquoi l'hypothèse d'une durée utile de 40 ans est peut-être optimiste. [...] (États-Unis, DOE, EIA, 1988, p. 1)

élevé). S'il n'est tenu compte que du sous-groupe des centrales nucléaires les plus chères (parachevées entre 1984 et 1987), le *Science Concepts* constate que leur coût (7,6 cents/kWh) est légèrement inférieur à celui des centrales au mazout dans le scénario de bas prix. Étant donné l'important effet immédiat de la répercussion des coûts d'immobilisation d'un réacteur dans le tarif de base, le coût de la première année de l'électronucléaire des réacteurs coûteux récents est estimé dépasser de 60 % le coût de la première année des centrales au mazout, mais demeure tout de même inférieur de 20 % au coût sur le cycle de vie de l'électricité produite au mazout, dans le cas du scénario de base employé par le *U.S. Department of Energy* (DOE) pour établir le prix futur du pétrole. On estime à 30 ans dans ces calculs le cycle de vie des centrales nucléaires et au mazout. Les projections des prix du pétrole utilisées sont celles du DOE. Dans le scénario de prix du pétrole bas, le pétrole se vendra 27,83 $US le baril (en dollars constants de 1987) en l'an 2000. Dans le scénario de base, son prix sera de 34,18 $US; dans le scénario de prix élevé, il sera de 43 $US. Dans ce dernier scénario, on prévoit que le prix du pétrole redescendra à 30 $US en 2010, par suite de l'utilisation de substituts qui réduiront la demande (Science Concepts, 1988).

L'*Energy Information Administration* (EIA) du DOE a publié récemment une étude portant sur les frais d'exploitation des centrales nucléaires américaines. Les constatations de l'EIA ne sont pas rassurantes pour l'industrie nucléaire des États-Unis. La question à laquelle l'EIA a tenté de répondre était la suivante : «Quels sont les facteurs qui ont provoqué la montée des frais d'exploitation non liés au combustible des réacteurs de puissance entre 1975 et 1984?» L'analyse a porté aussi bien sur les immobilisations post-opérationnelles que sur les frais d'exploitation et de maintenance. L'EIA n'a pas pu déterminer tous les facteurs qui ont contribué à la montée du coût de l'électronucléaire, ni n'a ventilé tous les coûts, mais elle est tout de même parvenue à d'importantes constatations. (États-Unis, DOE, EIA, 1988)

Elle a conclu que les principaux facteurs ayant contribué à la hausse des frais d'exploitation et de maintenance étaient : a) les effets réels de la hausse des salaires, le prix des matériaux, les frais d'exploitation et de maintenance décalés et l'inflation; b) le resserrement de la réglementation de la NRC; et c) les augmentations du coût de l'énergie de remplacement. Le vieillissement et l'expérience accrue en matière d'exploitation réduisent les frais d'exploitation et de maintenance, et ces frais tendent à diminuer à mesure qu'augmentent la valeur des nouvelles immobilisations. Certains États ont mis en oeuvre des programmes incitatifs (par lesquels les services d'électricité ont un meilleur rendement sur le capital si les centrales fonctionnent bien, mais sont pénalisés si ce n'est pas le cas), ce qui a contribué à accroître les frais d'exploitation et de maintenance. La hausse du coût des immobilisations post-opérationnelles a été attribuable essentiellement aux facteurs suivants : a) le resserrement de la réglementation de la NRC; b) des coûts inexpliqués; c) le vieillissement des installations; et d) le remplacement des générateurs de vapeur et l'obturation des fissures de la tubulure. Le recours à la maintenance, mesuré d'après les frais réels moyens d'exploitation et de

Les commissions des services publics étatiques rechignent de plus en plus à permettre l'inclusion dans le tarif de base des coûts entiers des centrales nucléaires (et de certaines centrales au charbon) parachevées. Entre 1980 et 1986, les organismes de réglementation des États ont abaissé les coûts admissibles des nouveaux réacteurs entrant en service des montants qui suivent (les sommes sont en devise américaine; l'année de l'entrée en exploitation est indiquée entre parenthèses) («Disallowances by State Regulators for Nuclear Units (1980-1986)», *Nuclear Industry*, mars-avril 1988, p. 64) :

Wolf Creek (Kansas, 1985)	1641,0 millions
Waterford 3 (Louisiane, 1985)	284,0 millions
Summer 1 (Caroline du Sud, 1984)	123,0 millions
Susquehanna 1 (Pennsylvanie, 1983)	287,0 millions
Susquehanna 2 (Pennsylvanie, 1985)	560,0 millions
Shoreham 1 (New York, inexploité)	1395,0 millions
San Onofre 2 et 3 (Californie, 1983 et 1984)	328,0 millions
Millstone 3 (Connecticut, 1986)	353,0 millions
Limerick 1 (Pennsylvanie, 1986)	368,9 millions
Grand Gulf 1 (Mississippi, 1985)	49,0 millions
Fermi 2 (Michigan, 1988/1985 licence d'exploitation pleine puissance)	680,0 millions
Callaway 1 (Missouri, 1984)	421,7 millions
Byron 1 (Illinois, 1985)	101,5 millions

Le montant précis des coûts non reconnus peut varier, les décisions des organismes de réglementation étant contestées devant les tribunaux. La plupart des services américains appartiennent à des intérêts privés et ce sont, au bout du compte, les actionnaires qui font les frais de ces décisions. On comprend aisément pourquoi ils hésitent à consentir de nouveaux investissements dans l'électronucléaire.

Le coût de l'électronucléaire est l'objet d'un débat aux États-Unis. Les premières centrales nucléaires présentent un net avantage sur les centrales au mazout. Le *Science Concepts* de Washington, dans une étude financée par le U.S. *Council for Energy Awareness*, estime que le coût sur l'ensemble du cycle de vie de l'électronucléaire, moyenné sur tous les réacteurs parachevés en 1987, est de 4,7 cents/kWh, alors que celui des centrales"au mazout est de 8,2 cents/kWh (scénario de prix du pétrole bas), de 9,7 cents/kWh (scénario de base) ou de 11,4 cents/kWh (scénario de prix du pétrole

Tableau 12 (suite) : Réacteurs de puissance en exploitation aux États-Unis le 1er janvier 1988

État	Réacteur / Type	Exploitation commerciale	Puissance électrique nette (MW)	Entrepreneur
Texas	South Texas Project 1 / PWR	88	1250	Westinghouse
Vermont	Vermont Yankee / BWR	72	528	General Electric
Virginie	Surry 1-2 / PWR	72/73	781/781	Westinghouse
	North Anna 1-2 / PWR	78/80	926/926	Westinghouse
Washington	WPPSS 2 / BWR	84	1100	General Electric
Wisconsin	Point Beach 1-2 / PWR	70/72	485/485	Westinghouse
	Kewaunee / PWR	74	535	Westinghouse

Notes : Les licences d'exploitation à faible puissance ou à pleine puissance des réacteurs dont l'exploitation a commencé en 1988 ont été délivrées avant la fin de 1987.

a) Une licence d'exploitation à faible puissance sans restriction a été délivrée pour le réacteur de Shoreham le 3 juillet 1985, mais son exploitation commerciale a été refusée.

b) Le réacteur Three Mile Island 2 est fermé depuis l'accident du 28 mars 1979 et n'est pas un réacteur autorisé. Le réacteur Three Mile Island 1 a été fermé le 28 mars 1979, mais la reprise de son exploitation commerciale a été permise le 8 novembre 1985.

Source : U.S. Council for Energy Awareness, *Electricity from Nuclear Energy*, édition de 1988, Washington, D.C., 1988, p. 9-19.

prolongation, le vieillissement du parc électrique américain est cause d'une dégradation du rendement de la production. Comme aucune capacité nouvelle n'est installée, la fiabilité du réseau laissera bientôt à désirer, ce qui est en fait déjà manifeste en Nouvelle-Angleterre. Le *New England Power Pool* a dû procéder à des baisses de tension à trois reprises en 1987, alors que deux centrales en état de marche, celle de Shoreham au Long Island, de New York, et celle de Seabrook, au Vermont, étaient inutilisées (Seabrook peut-être chargée, mais non exploitée, et demeure dans la catégorie des centrales en construction, bien qu'elle soit terminée à 100 %.). Bien que ces circonstances offrent au Canada la possibilité d'exporter de l'électricité, cette situation ne satisfait pas les Américains.

Tableau 12 (suite) : Réacteurs de puissance en exploitation aux États-Unis le 1er janvier 1988

État	Réacteur / Type	Exploitation commerciale	Puissance électrique nette (MW)	Entrepreneur
Michigan	Big Rock Point / BWR	65	69	General Electric
	Palisades / PWR	71	777	Combustion Engineering
	Fermi 2 / BWR	88	1100	General Electric
	Donald C. Cook 1-2 / PWR	75/78	1030/1100	Westinghouse
Minnesota	Monticello / BWR	71	545	General Electric
	Prairie Island 1-2 / PWR	73/74	530/530	Westinghouse
Mississippi	Grand Gulf 1 / BWR	85	1250	General Electric
Missouri	Callaway / PWR	84	1120	Westinghouse
Nebraska	Cooper / BWR	74	760	General Electric
	Fort Calhoun 1 / PWR	73	492	Combustion Engineering
New Jersey	Oyster Creek / BWR	69	650	General Electric
	Salem 1-2 / PWR	77/81	1106/1106	Westinghouse
	Hope Creek 1 / BWR	86	1067	General Electric
New York	Indian Point 2-3 / PWR	73/76	873/965	Westinghouse
	James A. FitzPatrick / BWR	75	816	General Electric
	Shoreham / BWR	(a)	809	General Electric
	Nine Mile Point 1-2 / BWR	69/88	610/1080	General Electric
	Robert E. Ginna / PWR	70	470	Westinghouse
Caroline du Nord	Brunswick 1-2 / BWR	77/75	821/821	General Electric
	Shearon Harris 1 / PWR	87	900	Westinghouse
	William McGuire 1-2 / PWR	81/84	1129/1129	Westinghouse
Ohio	Perry 1 / BWR	87	1205	General Electric
	Davis-Besse 1 / PWR	77	860	Babcock & Wilcox
Oregon	Trojan / PWR	76	1130	Westinghouse
Pennsylvanie	Beaver Valley 1-2 / PWR	76/87	833/836	Westinghouse
	Three Mile Island 1-2 / PWR	74/78 (b)	819/900	Babcock & Wilcox
	Susquehanna 1-2 / BWR	83/85	1050/1050	General Electric
	Peach Bottom 2-3 / BWR	74/86	1065/1065	General Electric
	Limerick 1 / BWR	86	1055	General Electric
Caroline du Sud	H.B. Robinson 2 / PWR	71	700	Westinghouse
	Oconee 1-3 / PWR	73/74/74	846/846/846	Babcock & Wilcox
	Catawba 1-2 / PWR	85/86	1129/1129	Westinghouse
	Summer 1 / PWR	84	885	Westinghouse
Tennessee	Sequoyah 1-2 / PWR	81/82	1148/1148	Westinghouse

Tableau 12 : Réacteurs de puissance en exploitation aux États-Unis le 1er janvier 1988

État	Réacteur / Type	Exploitation commerciale	Puissance électrique nette (MW)	Entrepreneur
Alabama	Joseph M. Farley 1-2 / PWR	77/81	829/829	Westinghouse
	Browns Ferry 1-3 / BWR	74/75/77	1065/1065/1065	General Electric
Arizona	Palo Verde 1-3 / PWR	86/86/88	1270/1270/1270	Combustion Engineering
Arkansas	Arkansas Nuclear 1-2 / PWR	74/80	850/912	Babcock & Wilcox
Californie	Diablo Canyon 1-2 / PWR	85/86	1084/1106	Westinghouse
	Rancho Seco 1 / PWR	75	918	Babcock & Wilcox
	San Onofre 1 / PWR	68	436	Westinghouse
	San Onofre 2-3 / PWR	83/84	1070/1080	Combustion Engineering
Colorado	Fort St. Vrain / HTGR	79	330	General Atomic
Connecticut	Haddam Neck / PWR	68	582	Westinghouse
	Millstone 1 / BWR	70	660	General Electric
	Millstone 2 / PWR	75	870	Combustion Engineering
	Millstone 3 / PWR	86	1153	Westinghouse
Floride	Crystal River 3 / PWR	77	850	Babcock & Wilcox
	Turkey Point 3-4 / PWR	72/73	666/666	Westinghouse
	St. Lucie 1-2 / PWR	76/83	839/839	Combustion Engineering
Georgie	Edwin I. Hatch 1-2 / BWR	75/79	775/781	General Electric
	Alvin W. Vogtle 1 / PWR	87	1122	Westinghouse
Illinois	Dresden 2-3 / BWR	70/71	794/794	General Electric
	Zion 1-2 / PWR	73/74	1040/1040	Westinghouse
	Quad Cities 1-2 / BWR	72/72	789/789	General Electric
	LaSalle 1-2 / BWR	84/84	1078/1078	General Electric
	Braidwood 1-2 / PWR	88/88	1120/1120	Westinghouse
	Byron 1-2 / PWR	85/87	1120/1120	Westinghouse
	Clinton 1 / BWR	87	933	General Electric
Iowa	Duane Arnold / BWR	75	565	General Electric
Kansas	Wolf Creek / PWR	85	1150	Westinghouse
Louisiane	River Bend 1 / BWR	86	940	General Electric
	Waterford 3 / PWR	85	1104	Combustion Engineering
Maine	Maine Yankee / PWR	72	825	Combustion Engineering
Maryland	Calvert Cliffs 1-2 / PWR	75/77	825/825	Combustion Engineering
Massachusetts	Pilgrim 1 / BWR	72	670	General Electric
	Yankee / PWR	61	175	Westinghouse

À la fin de 1987, des référendums avaient été tenus dans 13 États. Ces référendums portaient sur la fermeture des centrales en exploitation ou sur l'arrêt des travaux de construction d'autres centrales. Les 13 propositions avaient été défaites. Sept consultations ont eu lieu en 1976; deux ont été tenues depuis l'accident de Tchernobyl. Trois tentatives de fermer l'une des centrales en exploitation du Maine, la centrale Maine Yankee, ont échoué dans les proportions de 60-40 (1980), 55-45 (1982) et 59-41 (1987). La centrale Maine Yankee a produit de l'électricité pendant 15 ans, à un coût d'exploitation moyen de 2,5 ¢/kWh, l'un des plus bas coûts au monde (USCEA, 1988b). Au moins trois tentatives de fermeture de réacteurs de puissance en exploitation auront lieu en 1988 (en Californie, en Orégon et au Massachussetts).

2. Le programme actuel des réacteurs de puissance

Les États-Unis possèdent le plus vaste programme électronucléaire au monde. Le 1er janvier 1988, 109 réacteurs étaient en service, avec une puissance installée totale de 97,2 GW, soit 14 % de la puissance installée électrique totale du pays. Ces centrales ont fourni environ 18 % de l'électricité produite aux États-Unis en 1987. Trente-trois des 50 États ont accordé des permis d'exploitation de réacteurs nucléaires, l'Illinois venant en tête avec 13 réacteurs. Quatorze réacteurs supplémentaires sont en construction, d'une puissance globale de 16,6 GW, et deux réacteurs d'une puissance de 2,2 GW sont en commande. Quatre États (Vermont, Connecticut, New Jersey et Caroline du Sud) produisent plus de 50 % de leur électricité dans des centrales nucléaires, le Vermont venant en tête avec 76 % en 1987. Douze autres États produisent plus de 25 % de leur électricité dans des centrales nucléaires (USCEA, 1988a). Le tableau 12 donne la liste des centrales nucléaires en exploitation dans chaque état au 1er janvier 1988.

Les PWR ont dominé le programme américain, avec deux fois la puissance installée des BWR (65 299 MW par rapport à 32 802 MW, en juillet 1987). À l'exception de deux BWR, tous les réacteurs actuellement en construction aux États-Unis sont du type PWR (NEI, 1988, p. 13).

Même si ce programme, le plus important du monde, est une réalisation impressionnante pour le pays qui est à l'origine de la filière LWR, le désarroi frappe aujourd'hui le programme nucléaire américain. Aucune nouvelle centrale n'est planifiée aux États-Unis et la plus récente commande, abstraction faite des annulations, remonte à octobre 1973. Tous les réacteurs en construction aux États-Unis sont donc âgés d'au moins 15 ans. On a bien fait comprendre au Comité qu'aucune nouvelle commande de réacteur ne sera passée tant que durera la conjoncture.

La centrale américaine moyenne est aujourd'hui âgée de 19 ans. Bien que de nombreuses centrales, classiques et nucléaires, fassent l'objet de programmes de

maintenus dans des limites tolérables». La Commission a conclu que les problèmes étaient essentiellement liés à l'humain et non au matériel.

> Lorsque nous disons que les problèmes fondamentaux sont liés aux personnes, notre intention n'est pas de limiter ce terme aux erreurs commises par certaines personnes — même s'il s'en commet. Nous voulons dire de façon plus générale que notre enquête a révélé des problèmes liés au «système» qui fabrique, exploite et réglemente les centrales nucléaires. Il y a des problèmes structuraux dans les divers organismes, il y a des lacunes dans les divers processus et il y a un manque de communication entre les personnes et les groupes clés [...]
>
> Nous remarquons que la réglementation est une source de préoccupation. Il incombe évidemment à la *Nuclear Regulatory Commission* d'établir des règlements pour garantir la sûreté des centrales nucléaires. Nous sommes toutefois convaincus que les règlements ne peuvent à eux seuls garantir la sûreté. En effet, lorsqu'un règlement devient aussi volumineux et aussi complexe que ceux qui s'appliquent actuellement, il peut nuire à la sûreté nucléaire. Les règlements sont si complexes que le service public, ses fournisseurs et la NRC doivent déployer des efforts considérables pour s'assurer que les règlements sont respectés [...]
>
> La plus grande «préoccupation» de chacun est celle de la sûreté du matériel, ce qui diminue l'importance de l'élément humain dans l'électronucléaire. Nous sommes tentés de dire que, même si un effort considérable a été déployé pour garantir le fonctionnement optimal du matériel lié à la sûreté et à la disponibilité de tout le matériel de secours nécessaire, la NRC et l'industrie n'ont pas reconnu suffisamment que les êtres humains qui gèrent et exploitent les centrales constituent un important système de sûreté (États-Unis, *The President's Commission on the Accident at the Three Mile Island*, 1979, p. 8-10).

Le Comité est d'avis que certains de ces problèmes systémiques persistent dans le programme électronucléaire américain.

Les États-Unis ont mis fin aux travaux sur les réacteurs surrégénérateurs lorsque le Congrès a refusé toute aide additionnelle au projet du surrégénérateur de 350 MW de Clinch River, Tennessee. Entrepris en 1973, le projet de Clinch River avait coûté près de 2 milliards de dollars US lorsque le projet a été arrêté.

On a calculé que l'accroissement de la puissance installée d'origine nucléaire aux États-Unis depuis l'embargo pétrolier de 1973 avait permis de remplacer plus de 3,5 milliards de barils de pétrole importé, soit une économie d'environ 100 milliards $US. Le coût de l'accroissement de cette puissance installée s'est élevé à 130 milliards $US. En 1973, l'énergie nucléaire se classait cinquième aux États-Unis parmi les diverses sources d'électricité. Les centrales nucléaires dépassèrent les centrales alimentées au pétrole en 1980, les centrales alimentées au gaz en 1983 et les centrales hydro-électriques en 1984. Aujourd'hui, les centrales nucléaires sont en deuxième position, derrière les centrales au charbon.

Bien que la consommation totale d'énergie aux États-Unis en 1986 ait augmenté de seulement 2 % environ par rapport à 1973, la demande d'électricité a augmenté de plus de 40 %. Durant la même période, la demande d'énergie non électrique a baissé d'approximativement 11 %.

groupe comprenait un réacteur à eau bouillante à l'Argonne National Laboratory près de Chicago; un réacteur refroidi par sodium et modéré par graphite à Santa Susanna en Californie; un réacteur à eau lourde à Oak Ridge, au Tennessee; un surgénérateur expérimental à Idaho Falls; et le prototype de réacteur à eau pressurisée de 60 MW de Shippingport dont l'exploitation commença en 1957. Le réacteur de Shippingport fut le premier réacteur civil à être mis en service aux États-Unis. Il avait été construit par Westinghouse pour le compte de l'AEC. Il a été exploité comme réacteur de puissance jusqu'en 1974 pour terminer comme réacteur d'essai, avant d'être déclassé en 1982.

Avec l'aide de l'AEC, les entreprises privées commencèrent à construire des réacteurs civils. Après Shippingport, Westinghouse construisit le réacteur à eau pressurisée de 185 MW à Yankee Rowe au Massachusetts, qui fut mis en service en 1961. Babcock & Wilcox construisit le réacteur de 265 MW d'Indian Point 1 près de New York, participant ainsi à l'évolution du principe du réacteur à eau pressurisée. Par contre, General Electric opta pour le réacteur à eau bouillante et construisit le réacteur de 200 MW de Dresden 1 dans l'Illinois pour la Commonwealth Edison. Après ces débuts favorables, l'industrie nucléaire américaine se développa rapidement au cours des années 60 et 70.

L'accident survenu à l'unité 2 de la centrale nucléaire de Three Mile Island près de Harrisburg, en Pennsylvanie, le 28 mars 1979, a entraîné un important retard dans le programme nucléaire américain. La centrale a été lourdement endommagée, et des matières radioactives ont été rejetées dans l'environnement. La dose moyenne de rayonnement absorbée par la population vivant dans un rayon de cinq milles de la centrale a été évaluée à environ 10 % du rayonnement naturel annuel, et l'exposition maximale de la population en général à l'extérieur de cette limite a été estimée à 70 millirems. [Ce niveau d'exposition équivaut à environ la moitié des niveaux de sources naturelles, médicales, etc., auxquels une personne moyenne serait exposée pendant une année.] L'exposition de la population en général a été si faible qu'on a conclu qu'il n'y aurait aucune augmentation mesurable des taux de cancers, des troubles de développement et des effets génétiques. Néanmoins, l'accident a eu un impact profond. Selon les auteurs du *Report of the President's Commission on the Accident at Three Mile Island* de 1979 (p. 2) :

> ... L'accident a été déclenché par des défaillances mécaniques dans la centrale et s'est aggravé à cause d'une combinaison d'erreurs humaines commises en essayant de corriger la situation [...] Au cours des 4 jours qui ont suivi, la direction de la centrale, les agents fédéraux et de l'État et la population en général sont restés dans l'incertitude quant à l'étendue et à la gravité de l'accident. Il est toutefois clair que son incidence, au pays et à l'étranger, a suscité de profondes inquiétudes quant à la sûreté de l'énergie nucléaire [...]

La Commission a déclaré que ses résultats ne signifiaient pas que l'énergie nucléaire était en soi trop dangereuse pour être exploitée, mais que «des changements fondamentaux s'imposaient pour que ces risques [associés à l'énergie nucléaire] soient

Le second volet des activités d'ANDRA concerne l'évacuation des déchets radioactifs à longue période. Lorsque la deuxième usine de retraitement de La Hague deviendra opérationnelle, environ 4 000 à 5 000 m^3 de déchets à longue période seront produits chaque année. En l'an 2000, les déchets accumulés représenteront un volume d'environ 60 000 m^3. ANDRA est actuellement engagé dans un programme de recherche d'un site d'évacuation. Le granite, le sel, l'argile et les schistes argileux constituent des formations géologiques appropriées pour l'évacuation des déchets et la France possède un site de recherche dans chacune de ces formations. Une étude a été entreprise en 1987 pour choisir un site unique; cette étude devrait être terminée en 1990. L'étape suivante consistera à construire un laboratoire officiel sur le site choisi, le site devant être validé aux environs de 1995. La construction des installations pourrait être terminée au tout début du prochain siècle, mais ANDRA considère que des retards sont possibles.

Les Français considèrent la gestion des déchets radioactifs comme un problème *technique*; la solution ne peut venir d'un référendum ni dépendre de manifestations populaires. Contrairement à ce qui se passe en Suède et en Allemagne de l'Ouest, les administrations locales en France ne peuvent refuser un site choisi par ANDRA pour l'évacuation des déchets. Jusqu'à maintenant, le programme de gestion des déchets n'a pas suscité de mécontentement important dans la population en général, grâce en partie à un vaste programme d'information du public entrepris par ANDRA. Toutefois, la population serait fortement opposée à l'idée d'accepter des déchets radioactifs d'autres pays.

E. Le programme électronucléaire américain

1. L'évolution du nucléaire aux États-Unis

La première démonstration d'une réaction de fission en chaîne fut réalisée par Enrico Fermi sous les tribunes du Stagg Field à l'Université de Chicago. Fermi construisit une «pile atomique» à uranium naturel modérée au graphite fonctionnant à très faible puissance de façon à pouvoir être refroidie à l'air. Cette pile atteignit la criticité le 2 décembre 1942 et, immédiatement après, on construisit des piles plus puissantes à Hanford dans l'État de Washington, dans le but de produire du plutonium pour fabriquer une bombe atomique.

Plus tard, en 1946, le Congrès vota l'*Atomic Energy Act* qui portait sur la poursuite de la mise au point des armes nucléaires, mais qui définissait un cadre légal pour les applications industrielles. Aux termes de cette loi, l'*Atomic Energy Commission* (AEC) fut créée pour surveiller les activités nucléaires américaines. En 1954, le Congrès approuva la construction de 5 prototypes de réacteurs industriels. Ce

ANDRA a deux responsabilités : 1) gérer les sites d'évacuation existants dont l'un se trouve au Centre de la Manche dans la presqu'île du Cotentin; 2) concevoir de nouvelles installations de stockage à long terme, explorer et mettre le site en valeur, et construire ces installations. Le financement de ces activités, y compris le transport des déchets radioactifs vers les installations de stockage, est assuré directement par les producteurs de déchets, principalement l'ÉdF, mais aussi par des laboratoires de recherche, des hôpitaux, des universités et des industries. Les fonds publics ne sont pas utilisés pour la gestion des déchets, ANDRA signale qu'en 1982, des déchets radioactifs étaient produits, en France, au rythme de 2500 kg par habitant par année (France, CÉA, ANDRA, non daté).

Les déchets radioactifs qui doivent être évacués sont divisés en deux catégories. Les déchets à courte période sont des matériaux radioactifs dont la période est inférieure à 30 ans. Après 300 ans (dix fois la plus grande période possible dans ce groupe), les risques radiologiques résiduels sur le site d'évacuation seront si faibles que l'on pourra permettre l'accès à ce site. Ainsi, les Français considèrent que l'évacuation à de faibles profondeurs convient très bien pour les déchets à courte période. Les déchets à longue période, que leur activité soit faible, intermédiaire ou élevée, doivent être isolés de la population pendant des milliers d'années et, partant, ils doivent être enfouis dans des formations géologiques stables profondes (plusieurs centaines de mètres).

L'évacuation à faible profondeur de déchets à courte période comporte trois niveaux de protection : choix du site, conception des installations et emballage des déchets. L'objectif est de prévenir le transport des matériaux radioactifs par l'eau à l'extérieur du site. Au Centre de la Manche, la majeure partie des déchets est enfermée dans des conteneurs cylindriques en métal. Ces conteneurs sont conservés tels quels s'ils contiennent des déchets de faible activité; ils sont encapsulés dans des monolithes de béton s'ils contiennent des déchets de haute activité. Un système comportant des galeries d'inspection permet de contrôler le taux de radioactivité dans les installations. Commencé en 1969, le Centre de la Manche est passé sous le contrôle d'ANDRA en 1979. Ces installations ont une capacité de 485 000 m^3; au milieu de 1986, 350 000 m^3 de déchets avaient été mis en place. Avec un taux d'addition des déchets d'environ 30 000 m^3 par an, le Centre de la Manche sera rempli en 1991. Un nouveau site d'évacuation a été choisi à environ 250 km de Paris et l'autorisation de construire un dépôt souterrain a été accordée en 1987. Ces installations, appelées Centre de l'Aubé, auront une capacité d'un million de mètres cubes et elles pourront être exploitées pendant environ 30 ans. L'exploitation commerciale devrait débuter à la fin de 1990 ou au début de 1991. Afin de stabiliser la production de déchets à courte période de faible activité à environ 30 000 mètres cubes par an, un vaste programme visant à réduire la production de déchets a été mis en oeuvre dans les centrales nucléaires françaises.

mondiale étant, le bloc communiste inclus, de 32,1 millions d'U.T.S./année. La plus grande partie de cette capacité, 10,8 millions d'U.T.S./année, revient à l'usine de l'Eurodif située à Triscatin, le plus gros complexe d'enrichissement de l'uranium au monde. La COGEMA possède une part de 51,5 % dans l'Eurodif. L'Italie, l'Espagne et la Belgique sont les autres actionnaires. L'Eurodif peut fournir le combustible requis pour l'exploitation d'environ quatre-vingt-dix réacteurs de 1000 MW sur une base continue. Elle occupe actuellement environ 43 % du marché mondial de l'enrichissement de l'uranium (NEI, 1988; communication personnelle, CÉA, 14 avril 1988).

La COGEMA oeuvre aussi dans le domaine de la fabrication de combustible. Le combustible destiné aux GGCR et aux réacteurs surrégénérateurs à neutrons rapides est fabriqué par la SICN (Société Industrielle de Combustible Nucléaire), une filiale en propriété exclusive de la COGEMA. La Fragema, qui appartient à parts égales à la COGEMA et à la Framatome, commercialise le combustible destiné au LWR et fabriqué par la FBFC, qui appartient à la COGEMA (25 %), à la Framatome (25 %) et à l'Uranium Péchiney (50 %). Les combustibles à oxyde mixte (uranium-plutonium) sont fabriqués par la Commox, qui appartient à 60 % à la COGEMA et à 40 % à la Belgonucléaire. La France a acquis la capacité de fabriquer environ 1550 tonnes de combustible à métal lourd (uranium et plutonium) par année et elle occupe environ 19 % du marché (Ambassade du Canada à Paris, 1988; France, CÉA, 1987; communication personnelle, CÉA, 14 avril 1988).

Le retraitement du combustible épuisé est effectué dans les usines de la COGEMA à Marcoule et à La Haye. On effectue présentement un agrandissement important de l'usine de La Haye qui fera passer sa capacité de retraitement de 400 à 1600 tonnes de métal lourd par année. L'usine de Marcoule a une capacité de 600 tonnes par année. Une des nouvelles installations de retraitement d'une capacité de 800 tonnes par année de La Haye sera consacrée pendant ses 10 premières années d'exploitation à 30 clients étrangers de la COGEMA qui ont signé des contrats de retraitement et financé sa construction.

3. Gestion des déchets radioactifs

ANDRA, l'agence nationale de gestion des déchets radioactifs, est un organisme gouvernemental à but non lucratif établi en 1979 par décret ministériel au sein du CÉA. Cet organisme est responsable de la gestion à long terme de tous les types de déchets radioactifs provenant de toutes les sources. ANDRA reflète la décision du gouvernement français de séparer la gestion des déchets radioactifs des activités de réglementation et d'inspection.

La Framatome diversifiera aussi ses activités en se spécialisant dans des domaines autres que le nucléaire, par exemple dans les systèmes industriels informatisés, les compresseurs et les turbines, et le matériel et les services spécialisés destinés aux applications spatiales et militaires de haute technologie. Une autre démarche consiste à élaborer des plans d'accords avec des partenaires étrangers. Par exemple, la Framatome a conclu une entente avec la Babcock & Wilcox en vue de la commercialisation d'assemblages combustibles pour le PWR en Amérique du Nord; elle participe à une étude conjointe avec la KWU sur la faisabilité de l'introduction de l'énergie nucléaire en Indonésie; et, avec l'ÉdF et la Westinghouse, elle met au point des services de systèmes et des services de formation informatisés.

Le gouvernement français veut que la Framatome survive au ralentissement temporaire dans le domaine de la construction des réacteurs, quelles que soient les mesures à prendre.

Un objectif de la CÉA, découlant de la détermination de la France à devenir plus indépendante du point de vue énergétique, a été la prise en charge complète du cycle du combustible nucléaire. Cet objectif a été atteint. L'uranium est produit par la COGEMA, qui gère les deux tiers des réserves françaises de ce métal et qui produit 80 % de l'uranium exploité en France. Dans les pays non communistes, la COGEMA a accès à plus de 20 % des réserves d'uranium. Par sa participation directe ou par le biais de sociétés affiliées et de filiales, la COGEMA a acquis une part dans le domaine de l'uranium dans des pays comme le Canada, les États-Unis, l'Espagne, le Gabon, le Niger, la Zambie et le Sénégal. Au Canada, la COGEMA est le principal actionnaire de la société Amok Ltée (avec une participation directe de 38 % et, par le biais de sa filiale en propriété exclusive, la Compagnie de Mokta, une autre participation de 37 %), qui effectue de l'exploitation minière à Cluff Lake (Saskatchewan), et possède une part de 36,4 % dans la Cigar Lake Mining Corp., une entreprise en participation avec la *Saskatchewan Mining Development Corporation* et la Idemitsu. En 1986, la COGEMA a produit 7 700 tonnes de concentrés d'uranium, dont 2 600 tonnes provenant de ses mines françaises (Ambassade du Canada à Paris, 1988; France, CÉA, 1987).

La conversion du minerai en uranium métallique et en hexafluorure d'uranium est effectuée par la Comurhex, qui appartient à 49 % à la COGEMA. La capacité de raffinage et de conversion de la France est d'environ 25 500 tonnes d'uranium par année, soit 25 % de la capacité du monde non communiste. Sa part du marché est à peu près la même. La capacité d'enrichissement de l'uranium de la France est de 11,4 millions d'U.T.S. (unités de travail de séparation des isotopes[1]) par année, la capacité

---

1. L'unité de travail de séparation est une mesure de l'effort nécessaire pour séparer l'uranium en deux composantes, une enrichie et l'autre épuisée. Elle est indépendante du procédé de séparation employé. Le kilogramme est l'unité de travail de séparation; l'effort d'enrichissement et la consommation d'énergie sont calculés par kilogramme de travail de séparation effectué.

constaté aucun signe qui permette de conclure que le suivi de la charge accélérait le vieillissement des réacteurs.

En dépit de cette utilisation moins qu'optimale de certains de ses réacteurs, la France soutient que l'énergie électronucléaire est nettement avantageuse du point de vue coût. En 1985, le coût de production du kilowattheure d'énergie électronucléaire était de 0,180 franc tandis que le coût du kWh d'électricité produite par les centrales alimentées au charbon était de 0,405 franc, soit plus du double. L'ÉdF affirme que «le kWh français est le moins cher de l'Europe». Pour une centrale française devant être mise en service en 1992, l'EdF prévoit que le coût du kWh produit dans une centrale alimentée au charbon correspondra à plus de 150 % du coût du kWh produit dans une centrale nucléaire (ÉdF, 1986).

La Framatome a eu une performance impressionnante depuis le milieu des années 1970. En France, elle a construit trente-quatre réacteurs de 900 mégawatts entre 1977 et 1987, et douze réacteurs de 1300 mégawatts entre 1984 et 1987. À l'étranger, elle a construit cinq réacteurs de 900 mégawatts entre 1975 et 1985. Ainsi, au total, 51 réacteurs ont été construits en 13 ans seulement, soit une moyenne de presque quatre réacteurs par année. Dix réacteurs de 1300 et 1500 mégawatts seront construits en France entre 1988 et 1993, et quatre réacteurs seront construits à l'étranger pendant la même période. Les ventes à l'étranger ont été faites à la Belgique (trois réacteurs en service et un en construction), à l'Afrique du Sud (deux réacteurs en service), à la Corée du Sud (deux réacteurs en construction) et à la Chine (deux réacteurs en construction) (Framatome, 1988).

Les réacteurs qui sont encore en construction marquent la fin de la phase intensive de mise en oeuvre des réacteurs de la France. Avec la baisse du taux de croissance de la demande, les commandes de réacteurs peuvent tomber aussi bas qu'à un réacteur tous les 18 à 24 mois. Le gouvernement français s'est toutefois engagé à fournir le soutien requis, quel qu'il soit, pour maintenir la capacité de fabrication domestique de réacteurs pendant cette période d'activité réduite. La poursuite des travaux d'entretien des réacteurs en service en France, combinée à toutes les ventes de réacteurs au pays ou à l'étranger, sera suffisante pour maintenir un niveau essentiel d'activité. La Framatome intensifiera ses travaux sur l'amélioration de la tenue des réacteurs, l'augmentation de leur disponibilité, l'accroissement de la sûreté et le perfectionnement des instruments et des systèmes de commande. Elle étudie aussi des programmes d'extension de la durée de vie des réacteurs. Officiellement, les réacteurs français ont une durée d'utilisation prévue de 40 ans, mais ils pourraient être maintenus en service pendant une plus longue période. De plus, la Framatome construit des cuves sous pression pour réacteurs qui comprennent environ un tiers du nombre de soudures des cuves sous pression construites aux États-Unis. Par conséquent, les cuves construites en France sont moins sujettes à la fragilisation à la longue et devraient avoir une plus grande durée de vie.

Tableau 11 (suite) : Réacteurs de puissance en exploitation en France au 1er janvier 1988

Réacteur / Type	En exploitation depuis	Puissance électrique nette	Entrepreneur
Blayais-1 / PWR	1981	910 MW	Framatome
Blayais-2 / PWR	1983	910 MW	Framatome
Blayais-3 / PWR	1983	910 MW	Framatome
Blayais-4 / PWR	1983	910 MW	Framatome
Cruas Meysse-1 / PWR	1984	880 MW	Framatome
Cruas Meysse-3 / PWR	1984	880 MW	Framatome
Cruas Meysse-2 / PWR	1985	900 MW	Framatome
Cruas Meysse-4 / PWR	1985	880 MW	Framatome
Paluel-1 / PWR	1985	1 330 MW	Framatome
Paluel-2 / PWR	1985	1 330 MW	Framatome
Paluel-3 / PWR	1986	1 330 MW	Framatome
Paluel-4 / PWR	1986	1 330 MW	Framatome
Saint Alban-1 / PWR	1986	1 335 MW	Framatome
Saint Alban-2 / PWR	1987	1 335 MW	Framatome
Flamanville-1 / PWR	1986	1 330 MW	Framatome
Flamanville-2 / PWR	1987	1 330 MW	Framatome
Cattenom-1 / PWR	1987	1 300 MW	Framatome
Cattenom-2 / PWR	1987	1 300 MW	Framatome
Belleville-1 / PWR	1987	1 310 MW	Framatome
Nogent-1 / PWR	1987	1 310 MW	Framatome
Super-Phénix / FBR	1987	1 200 MW	Novatome

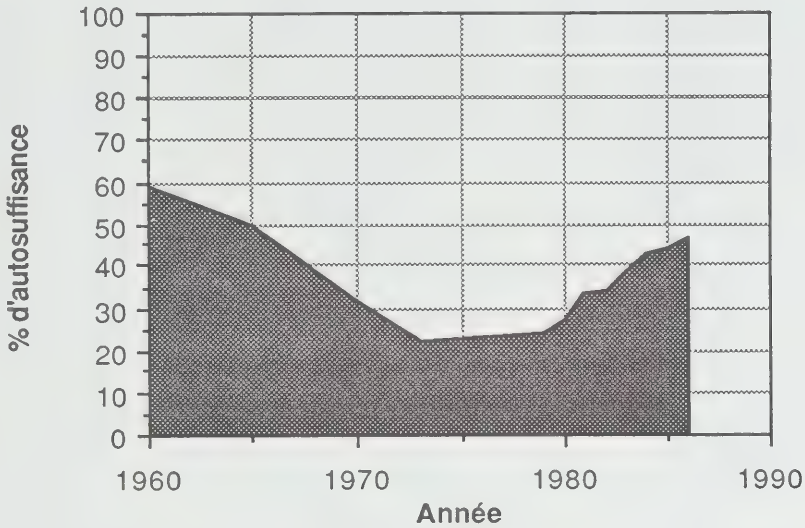
Source : France, Commissariat à l'Énergie Atomique, *Les Centrales Nucléaires dans le Monde*, édition de 1987, Paris, 1987, p. 22-23; France, Commissariat à l'Énergie Atomique, *Dossier France au 1er janvier 1988*, CEA/DPg–E/88-53/JCLR, Paris, 1988.

MW. Au cours du mois de pointe de juin, on a compté plus de 200 mises en service cycliques, les réacteurs de 900 MW tournant à moins de 40 % de leur capacité pendant environ 90 de ces cycles (ÉdF, 1986). Certains se sont inquiétés des contraintes que font subir à un réacteur ces fluctuations fréquentes de la puissance, mais les Français n'ont

Tableau 11 : Réacteurs de puissance en exploitation en France au 1^er^ janvier 1988

Réacteur / Type	En exploitation depuis	Puissance électrique nette	Entrepreneur
Chinon A-3 / GGCR	1967	480 MW	Industrie France
Chinon B-1 / PWR	1984	870 MW	Framatome
Chinon B-2 / PWR	1984	870 MW	Framatome
Chinon B-3 / PWR	1987	870 MW	Framatome
Chinon B-4 / PWR	1988	890 MW	Framatome
St-Laurent A-1 / GGCR	1969	480 MW	Industrie France
St-Laurent A-2 / GGCR	1971	515 MW	Industrie France
St-Laurent B-1 / PWR	1983	880 MW	Framatome
St-Laurent B-2 / PWR	1983	880 MW	Framatome
Chooz A-1 / PWR	1970	305 MW	A-F-W
Bugey-1 / GGCR	1972	540 MW	Industrie France
Bugey-2 / PWR	1979	920 MW	Framatome
Bugey-3 / PWR	1979	920 MW	Framatome
Bugey-4 / PWR	1979	900 MW	Framatome
Bugey-5 / PWR	1980	900 MW	Framatome
Phénix / FBR	1974	233 MW	Industrie France
Fessenheim-1 / PWR	1977	880 MW	Framatome
Fessenheim-2 / PWR	1978	880 MW	Framatome
Dampierre-1 / PWR	1980	890 MW	Framatome
Dampierre-2 / PWR	1981	890 MW	Framatome
Dampierre-3 / PWR	1981	890 MW	Framatome
Dampierre-4 / PWR	1981	890 MW	Framatome
Gravelines B-1 / PWR	1980	910 MW	Framatome
Gravelines B-2 / PWR	1980	910 MW	Framatome
Gravelines B-3 / PWR	1981	910 MW	Framatome
Gravelines B-4 / PWR	1981	910 MW	Framatome
Gravelines C-5 / PWR	1985	910 MW	Framatome
Gravelines C-6 / PWR	1985	910 MW	Framatome
Tricastin-1 / PWR	1980	915 MW	Framatome
Tricastin-2 / PWR	1980	915 MW	Framatome
Tricastin-3 / PWR	1981	915 MW	Framatome
Tricastin-4 / PWR	1981	915 MW	Framatome

Graphique 10 : Autosuffisance de la France en énergie primaire, 1960–1986



Source : Observatoire de l'Énergie, France.

Le tableau 11 donne de plus amples renseignements sur les réacteurs en exploitation en France.

En 1987, l'électronucléaire a représenté 69,8 % de la production totale d'électricité de France. Cette part a cru rapidement dans les années 80, comme le montrent les statistiques suivantes exprimant la part de l'électronucléaire dans le bilan de la production électrique totale : 1986, 69,7 %; 1985, 64,9 %; 1984, 58,7 %; 1983, 48,3 %; et 1982, 38,7 %. Aucun autre pays du monde ne fait aussi largement appel à la fission pour alimenter son réseau électrique. Et la France n'a pas l'intention de s'arrêter là, puisqu'elle projette produire les trois quarts de son électricité (et le tiers de l'énergie primaire totale dont elle aura besoin) à partir du nucléaire en 1990.

La capacité de l'électronucléaire dépasse déjà la charge de base et bon nombre des réacteurs 900 MW sont exploités par cycle, afin de répondre aux besoins de pointe. Le suivi de la charge se fait le plus couramment en mai et en juin. En 1985, il y a eu 935 mises en service cycliques quotidiennes dans le cas des réacteurs de la classe 900

type «CP2». Tous les 34 réacteurs de cette classe de 900 MW sont en service. Pour ce qui est de la classe 1 300 MW, tous les huit réacteurs du type «P4» sont en service et quatre des douze réacteurs du type «P4» étaient en service à la fin de 1984. Six réacteurs du type «N4» de la classe 1 500 MW sont en construction actuellement. Six petits réacteurs (quatre GGCR, un PWR et surrégénérateur) sont également en service en France. Au cours de 1988, la France prévoit raccorder à son réseau national deux réacteurs de classe 1 300 MW. (Framatome, 1988)

La réalisation du premier réacteur de 900 MW, le Fessenheim 1, a demandé 78 mois. La construction des premiers réacteurs CP1 de la classe 900 MW a demandé en moyenne 78 mois, mais les derniers réacteurs ont pu être construits sur une période moyenne de 60 mois. Il faut de 72 à 80 mois pour construire un réacteur de la classe 1 300 MW, depuis les débuts des travaux de génie civil au raccordement au réseau, mais le programme des travaux de certains de ces réacteurs est délibérément retardé parce que la demande d'électricité n'a pas cru aussi rapidement ces récentes années qu'on l'avait prévu (ÉdF, 1986).

En 1973, la France ne produisait à partir de sources nationales que 22,5 % de son énergie primaire; en 1986, la proportion était passée à 46,2 %, presque entièrement grâce à l'expansion du programme nucléaire. En l'an 2000, la France estime qu'elle sera autosuffisante entre 52 % à 58 % pour ce qui est de son énergie primaire. Le graphique 10 montre le changement dans l'autosuffisance énergétique de la France de 1960 à 1986. Le fléchissement de l'autosuffisance survenu entre 1960 et 1973 reflète la substitution du charbon français par du pétrole importé. L'électricité primaire représentait 32,7 % de la consommation française d'énergie primaire en 1986, et l'électronucléaire permettait de produire 69,7 % de l'électricité consommée. Il s'ensuit donc que l'électronucléaire permet à la France de produire 23 % environ de l'énergie primaire qu'elle consomme. Les Français estiment que l'électronucléaire répondra à 32 % de leur consommation d'énergie primaire en 1990 (comparativement à 1,8 % en 1973); les chiffres sont de 30 % pour le pétrole (66 % en 1973), 15 % pour le charbon (17,2 % en 1973), 12 % pour le gaz naturel (8,4 % en 1973), 8 % pour l'hydro-électricité (5,5 % en 1973) et 3 % pour toutes les formes d'énergie renouvelable (1,1 % en 1973).

2. Le programme actuel des réacteurs de puissance

La France comptait 53 réacteurs de puissance en service, d'une puissance installée nette totale de 44 133 MWe au 1er janvier 1988. Dix autres réacteurs sont en construction et ajouteront 13 410 MWe à la capacité de production de l'électronucléaire de France. Six vieux réacteurs de taille modeste ont été fermés.

La COGEMA est la plus importante filiale du CÉA. Ses 14 000 employés offrent toute la gamme des services associés au cycle du combustible nucléaire. Fait aussi partie du CÉA l'ANDRA (Agence nationale pour la gestion des déchets radioactifs). Depuis 1983, tous les intérêts du CÉA ont été regroupés dans une société de portefeuille, la CÉA-Industrie.

Framatome, créée en 1958, conçoit et fabrique les principaux éléments des réacteurs PWR : récipients sous pression, générateurs de vapeur, pressuriseurs et instrumentation du coeur. Framatome, qui compte 5 000 employés, s'est occupée des travaux de recherche et de développement et de la fabrication des systèmes d'approvisionnement en vapeur des trois séries de réacteurs PWR français. Framatome fabrique également du combustible pour réacteurs, fournit, assemble, teste et met en service des équipements nucléaires, et fait enfin l'inspection en service des réacteurs. Novatome, qui appartient à 70 % à Framatome, a construit le surrégénérateur de Creys-Malville. Framatome construit également des réacteurs de recherche et des réacteurs de propulsion pour sous-marins. En janvier 1986, Framatome a été restructurée; elle appartient maintenant à 35 % à la CÉA-Industrie et à 10 % à l'ÉdF.

Alsthom est un groupe de sociétés employant 40 000 personnes et un des deux plus grands fabricants de matériel lourd de France. Le tiers des activités d'Alsthom est consacré à la conception et à la fabrication de matériel de centrales électriques. La société est le seul fabricant de turbo-génératrices de France.

Sources : ÉdF, 1986; Canada, Affaires extérieures, Ambassade du Canada, Paris, 1988; Framatome, 1987.

En 1946, le Commissariat à l'énergie atomique (CÉA) a eu pour mission de promouvoir l'utilisation de l'énergie nucléaire en France. Les travaux de la CÉA ont abouti à la construction de trois réacteurs de puissance expérimentaux à Marcoule. Ces réacteurs étaient les prototypes des réacteurs GGCR (alimentation en uranium naturel, modération au graphite et refroidissement au gaz). En 1956, le gouvernement français demandait à l'ÉdF de construire la première centrale GGCR commerciale, ce qui s'est concrétisé par la réalisation des tranches A1, A2 et A3 de Chinon. Le plus grand réacteur GGCR construit en France, et le dernier, est le réacteur Bugey 1 d'une puissance nette de 515 MWe, raccordé au réseau en 1972. Après avoir mis au point, dans les années 60, des réacteurs à eau légère alimentés en uranium enrichi, la France décida en 1969 de fonder désormais son programme nucléaire sur les réacteurs PWR (ÉdF, 1986).

Ayant pris cette décision, le gouvernement français entreprit d'établir un programme nucléaire techniquement indépendant. Ses efforts aboutirent en 1981 à l'acquisition par le CÉA de l'intérêt détenu par Westinghouse dans Framatome et à la fin de ses ententes de fabrication sous licence avec ce fabricant américain de réacteurs.

La France a également choisi de standardiser la conception de ses produits pour réacteurs : les produits allaient être fabriqués en série, mais adaptables à différents emplacements. Le résultat a été la réalisation de trois groupes de réacteurs, de classes 900 MW, 1 300 MW et 1 500 MW. Afin de permettre une amélioration de la technologie des réacteurs, l'ÉdF a cependant permis, suivant une progression par étapes, la fabrication de réacteurs de sous-série, au sein d'une classe donnée. Ces réacteurs de sous-série sont des conceptions améliorées de la classe générale. Ainsi, la classe 900 MW compte six réacteurs de pré-série, dix-huit réacteurs de type «CP1» et dix réacteurs du

tout en sachant que le surrégénérateur allait vraisemblablement jouer un rôle majeur dans le développement à long terme de son programme nucléaire.

Les problèmes causés par l'embargo pétrolier de 1973 ont convaincu la France que l'indépendance énergétique était essentielle à ses intérêts. En 1974, le gouvernement français a chargé l'Électricité de France (ÉdF), service public d'électricité national, d'élaborer un programme nucléaire permettant de fournir à la nation le tiers de ses besoins énergétiques totaux d'ici l'an 1990. En 1987, la France a produit 70 % de son électricité à partir du nucléaire, soit plus que tout autre pays. La France ne le cède qu'aux États-Unis pour ce qui est de la capacité nucléaire installée. Près du sixième des mises en chantier de réacteurs nucléaires dans le monde ont lieu en France, dont le programme de construction de réacteurs nucléaires n'est dépassé que par celui de l'Union soviétique. Le directeur général de la Division de l'ingénierie et de la construction de l'ÉdF exprime bien comment la France a pu atteindre cette remarquable performance (ÉdF, 1986, p. 3) :

> L'ingrédient essentiel du succès du programme nucléaire français est la compétence extrême de chacun des secteurs y participant. Le succès revient également à la détermination du gouvernement, de l'ÉdF et de l'industrie à atteindre des objectifs bien définis. L'harmonisation judicieuse des compétences et des ressources a donné à notre industrie nucléaire une cohérence inégalée qui explique sa capacité.

L'une des raisons qui font que la France a pu adopter le nucléaire sans trop soulever d'opposition publique est peut-être le rôle capital que des scientifiques français ont joué dans le développement de la physique nucléaire. Henri Becquerel, Pierre et Marie Curie, Frédéric Joliot et d'autres se sont distingués dans cette discipline. Mais même cela n'explique pas tout le succès français. Ce qui est également remarquable, c'est la discipline que la France a su donner à l'entreprise.

Éléments clés du programme nucléaire français

Électricité de France, le plus grand service public d'électricité au monde, a été créé en 1946 par la nationalisation de plus de 1500 compagnies de production et de distribution d'électricité. ÉdF produit 90 % de l'électricité de la France, possède tout le réseau national de transmission et distribue 96 % de l'électricité. La société conçoit, construit, possède et exploite ses propres centrales nucléaires. Les ventes d'électricité de l'ÉdF ont atteint 140 milliards de francs (28 milliards $CAN) en 1986. La société est le plus important investisseur de France, les capitaux investis ayant atteint 37 milliards de francs (7,4 milliards $CAN) en 1986.

L'industrie nucléaire française s'articule sur deux pivots : le Commissariat à l'énergie atomique et ses filiales d'une part, et les grands fournisseurs nucléaires d'autre part, dont les principaux sont Framatome et Alsthom.

Le **Commissariat à l'énergie atomique** est une immense société publique, qui compte de nombreuses filiales et 40 000 employés; sa mission principale est la recherche et le développement nucléaires. Le CÉA exécute de la recherche fondamentale et appliquée, met au point des utilisations militaires de l'énergie atomique, s'intéresse à toutes les étapes du cycle du combustible nucléaire, dont la gestion des déchets radioactifs, et fournit son aide au gouvernement dans les domaines de la sûreté et de la sécurité nucléaires.

programme d'élimination portent sur l'enfouissement à la fois des déchets retraités et du combustible épuisé à Gorleben. Un milliard de marks environ (presque 700 millions $CAN) ont déjà été dépensés dans le cadre de ce programme.

En vertu de la législation ouest-allemande, les services publics d'électricité doivent faire la preuve, au moyen d'un plan mobile de six ans, qu'ils ont prévu quoi faire avec le combustible épuisé des réacteurs. Ils s'appuient notamment pour faire cette preuve sur l'usine de retraitement de Wackersdorf et sur le programme d'élimination des déchets de retraitement à Gorleben. Les services publics ne peuvent pas prétendre éliminer directement leur combustible épuisé, puisqu'ils ne répondraient plus aux exigences de la loi. À moins que l'élimination directe n'ait été suffisamment étudiée pour être acceptée comme méthode d'élimination sûre, les services publics ne peuvent donc abandonner le programme de retraitement du combustible irradié à Wackersdorf. Les représentants de l'Allemagne de l'Ouest ont fait observer que leur pays était le seul à avoir choisi provisoirement l'emplacement d'une installation d'élimination, mais cela n'est plus le cas depuis que les États-Unis ont décrété que la montagne Yucca, au Nevada, servirait d'emplacement pour une installation d'élimination (sous réserve des résultats des travaux d'investigation du site).

Les consommateurs d'électricité feront entièrement les frais du programme de gestion des déchets, puisque les services publics d'électricité allemands en absorbent les coûts qu'ils répercutent dans le tarif de base. Les gouvernements des États sont chargés de l'administration du programme, mais ils ne le financent pas.

D. Le programme électronucléaire français

1. L'évolution du nucléaire en France

La France compte 56 millions d'habitants et s'étend sur un territoire de 549 000 kilomètres carrés (212 000 milles carrés). Le Comité n'a visité en France que Paris et ses environs immédiats. Étant donné la centralisation du gouvernement français, il a pu s'entretenir avec les représentants de nombreux organismes du domaine nucléaire.

Le programme des réacteurs français s'est appuyé à l'origine sur un réacteur refroidi au gaz et modéré au graphite, alimenté en uranium naturel. Neuf réacteurs de ce type ont été construits, le premier ayant été le réacteur G-1 de 2 MW de Marcoule, qui a été raccordé au réseau en 1956, le dernier ayant été le réacteur Bugey-1 de 540 MW, raccordé au réseau en 1972. Quatre de ces réacteurs sont encore en service. La France a commencé à construire des réacteurs PRW dans les années 60, le premier à entrer en service, en 1967, ayant été le réacteur Chooz A-1 de 310 MW. En 1969, la France décidait d'articuler son programme futur d'électronucléaire sur le réacteur PWR,

L'opinion publique allemande s'oppose aussi très fortement au programme de gestion des déchets radioactifs, en dépit de la conviction du gouvernement que ce programme est solide et bien conçu. La recherche a porté sur l'utilisation du sel comme milieu de dépôt. En 1965, le gouvernement fédéral a acheté la mine de sel désaffectée d'Asse afin de mettre au point des méthodes de stockage des déchets radioactifs. De 1967 à 1978, environ 124 500 fûts de déchets faiblement radioactifs et 1300 fûts de déchets moyennement radioactifs ont été stockés dans la mine. Une modification apportée à la loi sur l'énergie atomique en 1976 prévoyait l'expiration des licences de stockage en 1978. Depuis, la mine d'Asse a servi à poursuivre les travaux de recherche sur l'emploi du sel comme milieu de dépôt des déchets radioactifs. On juge que la mine d'Asse ne convient pas à l'élimination des déchets hautement radioactifs, mais elle pourrait être rouverte et servir de dépôt pour les déchets faiblement et moyennement radioactifs (FRG, PTB, 1985).

Dans les années 70, l'intérêt porté à l'utilisation de formations géologiques autres que le sel a conduit à étudier la possibilité d'utiliser la mine de fer désaffectée Konrad, près d'Asse, comme dépôt souterrain de déchets à faible impact thermique. La mine Konrad est exceptionnellement sèche, puisqu'elle est recouverte de strates riches en argile. Le fait que les galeries de la mine se situent à une profondeur allant de 800 à 1300 mètres est également un avantage. Les démarches pour faire de la mine Konrad un dépôt souterrain ont été amorcées.

Également au milieu des années 70, le dôme de sel Gorleben au nord d'Asse a été choisi comme emplacement provisoire d'un dépôt souterrain pour des déchets radioactifs de toute catégorie. Si l'étude de l'emplacement confirme qu'il est acceptable et si le processus d'autorisation confirme le choix de ce site, la construction d'un dépôt souterrain pourrait commencer après 1995, et des déchets pourraient y être stockés à la fin du siècle.

Les travaux menés dans la mine de sel d'Asse et les études subséquentes menées pour le dôme de sel Gorleben, emplacements tous deux situés près de la frontière nord-est partagée avec l'Allemagne de l'Est, ont déclenché l'opposition du public, ce qui a retardé le programme. L'installation de stockage intermédiaire pour éléments de combustible épuisé de Gorleben est techniquement opérationnelle, mais n'a pas été mise en service en raison de contestations. La construction d'une deuxième installation de ce genre à Ahaus a été suspendue par ordre des tribunaux. Une installation de stockage pour déchets faiblement radioactifs au site de Gorleben est toutefois en service. Une demande de permis a été faite pour la construction d'une usine pilote, à Gorleben, pour le conditionnement des déchets hautement radioactifs avant leur élimination finale dans une installation, qu'on se propose également de construire dans ce dôme de sel. Un accident survenu en 1987 dans un puits d'exploration a retardé d'environ une année les travaux entrepris dans cette installation. Les études menées dans le cadre du

change actuel) pour réduire les émissions de gaz acides de ces centrales au lignite d'une capacité totale de 11 000 MW. Et même si elles étaient alimentées en charbon importé, au prix déprimé d'aujourd'hui, les centrales au charbon d'Allemagne pourraient à peine faire concurrence à l'électronucléaire, à son prix actuel.

La responsabilité publique, en Allemagne de l'Ouest, en cas d'accidents nucléaires est partagée entre les services publics et l'État. La responsabilité principale, jusqu'à concurrence d'un milliard de marks (environ 675 millions de dollars canadiens au moment de la rédaction du présent rapport), incombe à celui qui produit l'électricité. Le gouvernement fédéral garantit une couverture illimitée si les dommages devaient dépasser ce montant.

Les Allemands se sont également attachés à protéger leurs réacteurs contre les actes de sabotage ou les accidents. L'Allemagne a tenté de concevoir ses réacteurs de sorte qu'un opérateur ou un saboteur ne puisse contaminer l'environnement extérieur même s'il réussissait à endommager le réacteur. Les premiers réacteurs allemands avaient été construits dans un confinement de béton d'une épaisseur d'environ 0,5 mètre, conçu pour résister aux chocs d'un petit aéronef s'écrasant sur lui. Les nouveaux réacteurs sont protégés par une enveloppe de confinement de 1,8 mètre d'épaisseur, pouvant résister à l'impact d'un chasseur Tornado avec tout son équipement, ce qui fait un poids se situant entre 17 et 18 tonnes. L'écrasement d'un gros avion représente un moindre risque, car sa masse serait répartie sur une surface beaucoup plus grande de l'enveloppe de confinement. Comme l'a fait observer un représentant, la probabilité qu'un avion s'écrase dans un stade d'une capacité de 50 000 personnes est plus grande, et pourtant les stades ne sont pas protégés, tandis que les réacteurs allemands le sont.

En dépit d'un admirable dossier de sûreté des réacteurs, d'un des programmes de gestion des déchets radioactifs les plus perfectionnés du monde, d'une pénurie de ressources énergétiques indigènes, abstraction faite du charbon, et de graves problèmes de pollution de l'air, le programme nucléaire de l'Allemagne de l'Ouest suscite encore beaucoup d'opposition de la part du public.

3. Gestion des déchets radioactifs

Le programme nucléaire ouest-allemand porte également sur des installations d'enrichissement de l'uranium, des usines de fabrication d'oxyde d'uranium et d'oxydes mixtes, des installations de stockage provisoire du combustible épuisé et des déchets de réacteur, une installation de retraitement du combustible épuisé (en cours d'établissement à Wackersdorf, en Bavière) et un dépôt souterrain permanent des déchets radioactifs (qu'on prévoit établir dans le dôme de sel de Gorleben). En attendant que l'usine de retraitement de Wackersdorf entre en service, les Allemands font retraiter le combustible épuisé de leurs réacteurs à contrat par la société française COGEMA et par la compagnie britannique BNFL (*British Nuclear Fuels Limited*).

européen qui projette de construire un surrégénérateur prototype en Allemagne de l'Ouest (RWE, 1988). Ces exemples montrent l'ampleur de la coopération internationale entre les services publics d'Europe de l'Ouest dans le domaine de la construction des réacteurs, notamment pour ce qui est des surrégénérateurs, coopération qui permet également d'atténuer le risque financier. Le temps mis à délivrer la licence d'exploitation du réacteur de Kalkar menace cependant de compromettre cette coopération.

Le gouvernement ouest-allemand a déclaré au Comité que l'énergie nucléaire est une composante essentielle du système énergétique national, et même que le nucléaire et le solaire sont les formes d'énergie de l'avenir. Le défi principal est d'adapter ces formes d'énergie à la conjoncture ouest-allemande. Le maintien de la qualité de l'environnement est une des principales justifications du programme nucléaire ouest-allemand, l'accumulation de dioxyde de carbone dans l'atmosphère étant en effet jugée comme un des plus graves problèmes environnementaux de l'avenir. Selon des représentants du gouvernement, c'est la gestion des déchets radioactifs qui inquiète le plus le public.

À la suite de catastrophe de Tchernobyl, la Commission allemande de sûreté des réacteurs a réétudié la sûreté des réacteurs ouest-allemands, et a conclu qu'il n'y avait aucune raison de remettre en doute cette sûreté. Le programme nucléaire allemand n'a jamais été entaché d'un accident important. Pour un dirigeant de la RWE, «Tchernobyl prouve simplement que de tels accidents sont possibles uniquement en raison de la mauvaise construction et de la mauvaise exploitation d'un réacteur, ce que nous savions déjà».

La RWE estime que l'Allemagne de l'Ouest n'aura pas besoin, d'ici la fin du siècle, d'accroître sa capacité de production électronucléaire. Néanmoins, le service public continuera de planifier avec la KWU le réacteur de l'an 2000. Ces travaux sont considérés essentiels au maintien et à l'expansion des connaissances en matière de développement des réacteurs allemands. Plusieurs milliards de dollars devront être investis pour préserver l'option nucléaire jusqu'à ce qu'elle soit de nouveau nécessaire en Allemagne de l'Ouest. Cet investissement, estiment les Allemands, est nécessaire à l'avenir de leur pays.

Dans les conditions actuelles, l'électronucléaire est la solution la plus rentable pour l'Allemagne de l'Ouest. La RWE établit entre 10 et 12 pfennigs/kWh le coût moyen projeté de l'électronucléaire au début des années 90; le coût de l'électricité produite dans les centrales alimentées par du charbon extrait en Allemagne sera de 15 à 17 pfennigs, compte tenu des nouvelles exigences de protection de l'environnement très strictes auxquelles devront répondre ces centrales. Les Allemands estiment en outre que l'écart s'agrandira avec le temps. La RWE a affirmé au Comité qu'elle dépensait actuellement 6 milliards de marks (environ 4 milliards de dollars canadiens au taux de

Tableau 10 : Réacteurs de puissance en exploitation en Allemagne de l'Ouest au 1er janvier 1988

Réacteur / Type	En exploitation depuis	Puissance électrique nette	Entrepreneur
AVR Jülich / HTR	1969	13 MW	BB-Krupp
Obrigheim / PWR	1969	340 MW	Siemens
Stade / PWR	1972	630 MW	Siemens
Biblis A / PWR	1975	1 146 MW	Siemens-KWU
Biblis B / PWR	1977	1 240 MW	Siemens-KWU
Würgassen / BWR	1975	640 MW	AEG
Neckarwestheim-1 / PWR	1976	795 MW	Siemens-KWU
Brunsbüttel / BWR	1977	770 MW	AEG-KWU
Karlsruhe KNK-2 / Fast Breeder	1978	17 MW	Interatom
Isar-1 (Ohu) / BWR	1979	870 MW	AEG-KWU
Unterweser / PWR	1979	1 230 MW	Siemens-KWU
Philippsburg-1 / BWR	1980	864 MW	AEG-KWU
Philippsburg-2 / PWR	1985	1 268 MW	KWU
Grafenrheinfeld / PWR	1982	1 225 MW	KWU
Krümmel / BWR	1984	1 260 MW	AEG-KWU
Gundremmingen II-B / BWR	1984	1 249 MW	KWU
Gundremmingen II-C / BWR	1985	1 249 MW	KWU
Grohnde / PWR	1985	1 290 MW	KWU
Brokdorf / PWR	1986	1 307 MW	KWU
Mülheim Kärlich / PWR	1987	1 227 MW	RWE
Hamm-Uentrop / THTR	1987	296 MW	Konsortium THTR

Source : France, Commissariat à l'Énergie Atomique, *Les Centrales Nucléaires dans le Monde*, édition de 1987, Paris, 1987, p. 16-17; Breest, H.-Ch., *Nuclear Energy in the Federal Republic of Germany*, édition nº 101, Ministère fédéral de l'Environnement, de la Conservation de la nature et de la Sûreté nucléaire, République fédérale d'Allemagne, mars 1988, fig. 2.

300 MW de Kalkar. Ce réacteur de Kalkar est parachevé, mais le gouvernement de l'État a refusé d'en autoriser l'exploitation.

2. Le programme actuel des réacteurs de puissance

L'Allemagne de l'Ouest compte 22 réacteurs de puissance en exploitation aujourd'hui, d'une puissance installée nette totale de 18 826 MWe. Trois autres réacteurs sont en construction et un réacteur parachevé attend son permis d'exploitation. Ces quatre derniers réacteurs ajouteront une puissance installée de 4 052 MWe. Six des vieux réacteurs ont été retirés du service. Neuf projets ont par ailleurs été présentés au gouvernement, mais la réduction de la demande d'énergie en Allemagne remet en question leur nécessité avant la fin du présent siècle. Le tableau 10 présente des renseignements sur le programme nucléaire actuel de l'Allemagne de l'Ouest.

En 1986, 29,6 % de l'électricité de l'Allemagne de l'Ouest provenait de centrales nucléaires. En l'an 2000, cette part devrait passer à 35 %. Toutefois, l'opposition au développement du nucléaire s'est renforcée, notamment avec la montée politique du Parti Vert, et le programme nucléaire allemand est en difficulté. Le retard le plus important survenu dans le programme allemand est celui du surrégénérateur de 300 MW de Kalkar, projet que le gouvernement ouest-allemand a lancé en 1972 en collaboration avec les Pays-Bas et la Belgique. Bien que ce réacteur soit entièrement prêt à être chargé depuis 1986, le gouvernement de l'État du Rhin-Nord-Westphalie refuse de délivrer la licence d'exploitation. La RWE détient un intérêt de 68,85 % dans la société de portefeuille ouest-allemande SBK (Schnell-Brüter-Kernkraftwerkgesellschaft mbH Gemeinsames Europäisches Unternehmen, Essen) qui a construit et qui exploitera le réacteur de Kalkar. Des compagnies d'électricité hollandaises et belges détiennent la majeure partie du reste des intérêts, tandis qu'une petite part appartient à des services publics britanniques (RWE, 1988).

Si l'on fait abstraction du FBR de Kalkar, l'actuelle phase du programme nucléaire ouest-allemand prendra fin avec le parachèvement des trois réacteurs PWR qui restent. Le Comité a par ailleurs appris qu'aucune commande supplémentaire ne sera placée (à moins que la demande d'électricité ne reprenne) tant que les réacteurs de puissance de la première génération ne seront pas mis hors service et qu'ils devront être remplacés.

La SBK détient un intérêt de 16 % dans le surrégénérateur français Super-Phénix de 1200 MW situé à Creys-Malville, près de Lyon. Elle aura par conséquent droit à une proportion égale de l'électricité produite par le Super-Phénix. La part de la RWE est égale aux trois quarts de celle de la SBK, soit 12 % du Super-Phénix. La RWE détient également un intérêt de 7,5 % dans un projet de construction d'une nouvelle centrale nucléaire en Suisse, tandis que la SBK détient une part de 51 % dans un consortium

au pouvoir dans certains États et, puisque le gouvernement fédéral a délégué l'autorité de la délivrance des licences d'exploitation des réacteurs aux gouvernements étatiques, cette coopération s'est évanouie dans certains cas. C'est cette conjoncture politique qui retarde la mise en service du surrégénérateur de Kalkar.

Les travaux de recherche et de développement dans le domaine de l'énergie nucléaire n'ont pu commencer en Allemagne de l'Ouest qu'en 1955, à la signature du Traité de souveraineté de Paris. Le gouvernement allemand a par la suite établi des grands centres de recherche nucléaire à Karlsruhe et à Jülich, a passé des ententes de coopération bilatérale avec des pays comme la France et les États-Unis, et s'est joint à l'AIÉA, l'organisme chargé des questions de l'énergie nucléaire de l'OCDE, au CERN (Organisation européenne pour la recherche nucléaire) et à l'EURATOM (Communauté européenne de l'énergie atomique). Des industriels allemands ont par ailleurs collaboré avec des sociétés américaines à mettre au point des réacteurs, Siemens avec la Westinghouse pour la conception des réacteurs PWR, et l'AEG avec la General Electric pour la conception des réacteurs BWR. Vers 1970, l'Allemagne de l'Ouest n'avait plus besoin d'aide technique étrangère pour concevoir ses propres réacteurs. La Kraftwerk Union (KWU) a alors été créée par la société Siemens et par l'AEG-Telefunken, dans le but de concevoir une centrale nucléaire allemande ainsi que les dispositifs de sûreté connexes (Breest, 1988).

Non seulement l'Allemagne de l'Ouest a-t-elle pris ainsi la tête du peloton des pays industrialisés en matière de développement des réacteurs de puissance, mais encore elle a commencé à leur faire concurrence sur le marché de l'exportation.

En 1968, l'Allemagne de l'Ouest décrochait sa première commande, pour le réacteur Atucha de 320 MW en Argentine. Les Allemands ont ensuite vendu un réacteur de 450 MW aux Pays-Bas en 1969, un réacteur de 700 MW à l'Autriche en 1971, puis un réacteur de 920 MW à la Suisse, en 1972 (RFA, Ministère fédéral de la Recherche et de la Technologie, 1974).

L'Allemagne de l'Ouest a centré son programme des réacteurs commerciaux sur le LWR, en versions PWR et BWR. Tournée vers l'avenir, elle a également construit un réacteur haute température expérimental (HTR) de 15 MWe et récemment terminé la construction d'un réacteur haute température au thorium (THTR) de 300 MWe de taille commerciale. Comme il fonctionne à température de caloporteur plus élevée que le LWR, le HTR permet d'atteindre de meilleurs rendements. En le faisant fonctionner sur le cycle du thorium, on se donne une autre possibilité d'approvisionnement en combustible. Les réacteurs HTR seraient également plus sûrs que les réacteurs LWR.

Enfin, un surrégénérateur (FBR) expérimental refroidi au sodium de 17 MWe, dont on a commencé l'exploitation à Karlsruhe en 1978, a été le précurseur du FBR de

danger. Si le taux de rayonnement est trop élevé, le lingot est tout simplement conservé jusqu'à ce que le taux de radioactivité devienne acceptable.

Le Comité est impressionné par l'ampleur et la conception du programme suédois de gestion des déchets radioactifs. Le Comité est en faveur du maintien de comptes gouvernementaux distincts alimentés par les utilisateurs de l'électricité d'origine nucléaire et consacrés au déclassement des centrales.

C. Le programme électronucléaire ouest-allemand

1. L'évolution du nucléaire en Allemagne de l'Ouest

La République fédérale d'Allemagne (RFA), ou Allemagne de l'Ouest, a une superficie de 249 000 kilomètres carrés (96 000 milles carrés) et une population de 61 millions de personnes. Elle se compose de 11 États fédéraux, dont Berlin Ouest. L'état le plus populeux est le Rhin Nord-Westphalie, avec 17 millions d'habitants. La capitale, Bonn, et la ville d'Essen, où est situé le plus grand service public d'électricité allemand, la Rheinisch-Westfälisches Elektrizitätswerk (RWE), sont situées dans cet État. Le Comité s'est rendu dans ces deux villes.

Quatre ministères sont chargés de veiller au programme nucléaire au niveau fédéral. Le ministère fédéral de la Recherche et de la Technologie s'occupe de soutenir la recherche et le développement dans le domaine de l'énergie nucléaire. Le ministère fédéral des Affaires économiques veille pour sa part à l'utilisation de l'énergie nucléaire, qui est une importante source d'énergie en Allemagne. La réglementation de la sûreté nucléaire relève du ministère fédéral de l'Environnement, de la Conservation de la nature et de la Sûreté nucléaire. Enfin, le ministère des Affaires extérieures veille au respect des engagements internationaux de l'Allemagne de l'Ouest dans le domaine du nucléaire (Breest, 1988).

Les services publics d'électricité, qui détiennent les permis d'exploitation des réacteurs et qui exploitent les réacteurs de puissance sont des sociétés privées, bien que les municipalités et les États puissent détenir une partie de leurs capital-actions. Les organismes étatiques de délivrance des licences et de surveillance sont chargés de l'exécution des lois fédérales portant sur le nucléaire pour le compte du gouvernement central, sous la supervision du ministère fédéral de l'Environnement, de la Conservation de la nature et de la Sûreté nucléaire. Le gouvernement fédéral et celui des États ont étroitement collaboré par le passé à développer le nucléaire, notamment par le financement de centres de recherches nucléaires et de la recherche universitaire. Le Parti démocratique social a toutefois déclaré la guerre à l'énergie nucléaire, qu'il estime dangereuse depuis l'accident de Tchernobyl, et désire que toutes les centrales nucléaires allemandes soient graduellement mises hors service d'ici 10 ans. Les Démocrates sont

La société Studsvik a vu le jour en 1947 sous le nom de *AB Atomenergi*, une entreprise mixte État-secteur privé. La société commença à mettre au point un réacteur à eau lourde, jusqu'à ce que la Suède adopte le réacteur à eau légère dans les années 60. La Studsvik conçut et construisit le réacteur Agesta pour le système de chauffage régional de Stockholm. En 1969, la Studsvik fut complètement nationalisée et une société distincte, ASEA-ATOM, fut formée. Cette dernière entreprise appartenait à parts égales à l'ASEA et l'État. En 1978, la société d'État *AB Atomenergi* fut privatisée et devint la *Studsvik Energiteknik AB*. Aujourd'hui, la Studsvik fait face à une grande compétition et, n'ayant pu réaliser les profits escomptés en 1985 et 1986, elle a dû réduire son personnel et réorganiser ses opérations. En 1987, les revenus de la Studsvik dépassaient les 100 millions de dollars (CAN) et se ventilaient ainsi : environ 30 millions provenant de l'industrie nucléaire suédoise; 33 millions provenant des 12 millions provenant d'organismes nucléaires canadiens dans le cadre de contrats ayant fait l'objet de soumissions; 10 millions de dollars de droits payés par les universités pour des travaux de recherche effectués dans les installations de la société; 12 millions pour des projets spéciaux avec le gouvernement; et, enfin, 3 millions de dollars de subventions du gouvernement pour des travaux de R et D réalisés en collaboration avec l'industrie.

La Studsvik traite des déchets de faible activité et d'activité intermédiaire provenant de centrales nucléaires, d'hôpitaux, de laboratoires de recherche et de l'industrie. Elle incinère aussi des déchets de centrales provenant d'Allemagne de l'Ouest; les cendres sont ensuite enrobées dans du béton ou du bitume et renvoyées en Allemagne pour évacuation finale. La Studsvik a récemment terminé les travaux menés dans le cadre du projet AMOS, un programme complet de modernisation de toutes ses installations de traitement des déchets. Ce programme de modernisation comprenait la construction d'un nouveau bâtiment pour le traitement des déchets solides et liquides, d'une installation de stockage intermédiaire souterraine ainsi que des installations portuaires pour pouvoir accueillir le *M/S Sigyn*. Le système d'incinération de la Studsvik consiste en un incinérateur moderne à plusieurs chambres commandé électroniquement, conçu pour brûler des déchets de faible activité. Les cendres obtenues sont enrobées dans du béton. L'incinération permet de réduire de cent fois le volume des déchets. L'exploitation de l'incinérateur a débuté en 1977 et, en 1988, 3500 tonnes de déchets ont été brûlés. L'incinérateur se classe ainsi parmi les plus grands incinérateurs de déchets radioactifs au monde. La Studsvik doit vendre un incinérateur de capacité double aux Laboratoires nucléaires d'Oak Ridge, aux États-Unis. Elle s'attend à en vendre d'autres (Suède, *Studsvik Nuclear*, 1987).

La société Studsvik a aussi mis au point un four à induction pour fondre les métaux irradiés. On évite ainsi la tâche difficile de décontamination de structures compliquées telles que les conduites des chaudières. Le métal est découpé et fondu; le lingot obtenu est ensuite passé au scanner pour vérifier qu'il peut être recyclé sans

faisceaux de combustible épuisé sont transférés dans les conteneurs de stockage qui sont placés en des endroits prédéterminés dans les piscines de stockage (Suède, SKB, 1986).

Les déchets radioactifs de faible activité et d'activité intermédiaire sont envoyés aux installations SFR à Forsmark, un dépôt final pour les déchets de réacteurs. Les déchets de faible activité sont des déchets dont le taux de rayonnement est si faible qu'ils peuvent être manipulés sans blindage. Les déchets d'activité intermédiaire requièrent un blindage, mais ils ne nécessitent pas de refroidissement. Ces déchets ne contiennent pratiquement pas de radionucléides de longue période et l'on considère qu'après environ 500 ans, ils sont inoffensifs pour les êtres humains et l'environnement. Selon les hypothèses les plus pessimistes utilisées dans l'évaluation des effets environnementaux du SFR, ces déchets contribueraient à accroître le rayonnement de fond naturel dans la région de quelques pour cent. Le SFR est installé dans la roche de fond à 50 mètres au-dessous du lit de la Baltique. La profondeur de l'eau au-dessus du dépôt est de 5 mètres. Cette région de Suède subit encore le poids de la dernière nappe de glace qui a recouvert le pays il y a 9000 ans environ. Dans 500 ans, elle se trouvera au-dessus du niveau de la mer, mais, à ce moment-là les déchets seront pratiquement inoffensifs. Le SFR a été installé sous la Baltique car les eaux souterraines sont stagnantes et personne ne creusera là pour obtenir de l'eau douce [Suède, SKB, non daté(a)].

Le SFR consiste en des chambres de stockage et en un silo aménagé dans une série de cavernes que l'on atteint par deux tunnels d'un kilomètre de long creusés à partir de la côte. Le silo (il y a en aura quatre) renfermera les matériaux les plus radioactifs, principalement des résines échangeuses d'ions solidifiées dans des moules de béton ou dans des conteneurs métalliques. Le silo est divisé en cellules carrés de 2,5 m de côté. Les conteneurs de déchets sont mis en place dans les cellules et noyés dans du ciment. Le silo repose sur un lit de sable et d'argile; l'espace entre la paroi du silo et la roche environnante est comblé avec de l'argile. Divers types d'emballage sont utilisés pour les déchets placés dans les chambres de stockage, suivant la radioactivité du déchet et les méthodes de manutention utilisées dans les centrales nucléaires. La construction du SFR a été terminée en 1988 et le Comité a visité cette installation quelques semaines avant qu'elle commence à recevoir des déchets provenant de centrales nucléaires. La construction de la première phase du SFR a coûté environ 140 millions de dollars canadiens [Suède, SKB, non daté(a)].

Studsvik Energiteknik AB est un centre de recherche sur l'énergie installé à environ 100 km au sud de Stockholm sur la côte de la Baltique. Le Comité a visité les installations de la Studsvik en raison des similitudes que ces installations présentent avec les Laboratoires nucléaires de Chalk River et, plus particulièrement, en raison des travaux menés dans ces laboratoires dans le domaine de la gestion des déchets de centrales nucléaires.

Toutes les centrales nucléaires suédoises sont situées le long de la côte et chacune est dotée de ses propres installations portuaires. Le SKB a mis sur pied un système complet de transport des matériaux radioactifs par mer. Le combustible épuisé est stocké dans des travées remplies d'eau sur chaque site pendant au moins un an, après quoi il est mis dans des châteaux qui sont transportés par camion sur un transroulier spécialement conçu, le *M/S Sigyn*, pour être envoyés à une installation de stockage. Le combustible nucléaire épuisé est placé dans un château d'acier blindé de 80 tonnes pouvant contenir 3 tonnes de combustible. Le château de transport est installé sur un châssis et est soulevé hydrauliquement par un véhicule transportant à la fois le châssis et le château. Cette cargaison peut être roulée ou soulevée par une grue sur le *Sigyn*, qui peut transporter 10 de ces châteaux. Le navire est aussi utilisé pour transporter des déchets de faible activité et d'activité moyenne (déchets de réacteurs) vers un dépôt final à la centrale nucléaire de Forsmark. Le *M/S Sigyn* effectue environ 30 voyages par an entre les quatre centrales nucléaires, l'installation centrale de stockage du combustible et le dépôt de déchets [Suède, SKB, non daté(b)].

Le *M/S Sigyn* est un navire à double coque et à double fond équipé de plusieurs cloisons étanches. De conception suédoise mais de construction française, le navire possède deux systèmes de propulsion indépendants; l'électricité est fournie par trois génératrices, chaque génératrice pouvant satisfaire la demande totale du navire. Un système moderne de lutte contre les incendies protège toutes les parties du navire. Un réservoir rempli d'eau protège les quartiers de l'équipage des rayonnements provenant de la cale et des murs en béton séparent les salles des machines de la cale. Il est équipé de détecteurs de rayonnement gamma et de neutrons [Suède, SKB, non daté(b)].

L'installation centrale de stockage du combustible épuisé d'Oskarshamn est connue sous le nom de CLAB. Ce système de stockage à piscine est conçu pour recevoir le combustible des quatre centrales pour un stockage intermédiaire d'environ 40 ans avant l'évacuation finale. Le bâtiment de stockage du combustible a été creusé dans la roche de fond, et le toit de la caverne de 120 mètres de longueur se trouve à 25-30 mètres au-dessous de la surface. Dans sa configuration initiale, le CLAB comporte quatre piscines de stockage reliées les unes aux autres, chaque piscine pouvant contenir 750 tonnes de combustible épuisé. L'installation peut être agrandie avec des cavernes supplémentaires construites parallèlement à la première. Le CLAB a été mis en service en 1985. Le coût total de construction s'est élevé à environ 1700 millions de couronnes, soit 325 millions $CAN (Suède, SKB, 1986).

Un véhicule terminal transporte le château du navire au CLAB et le château est déchargé dans un sas du bâtiment récepteur. Le château est soulevé du véhicule à l'aide d'une grue, puis il est refroidi à la température ambiante dans une chambre de préparation pour être enfin déchargé sous l'eau par des machines télécommandées. Les

. Pour l'essentiel, le problème des déchets radioactifs sera résolu par la génération de Suédois qui utilisent l'électricité produite par les centrales nucléaires, c'est-à-dire que les générations futures n'en subiront pas le fardeau.

. Aucune décision relative à la conception du dépôt du combustible nucléaire épuisé ne sera prise avant l'an 2000 environ, afin que toute décision s'appuie alors sur de solides connaissances.

. Les systèmes de gestion des déchets seront conçus de façon à ce que les exigences relatives au contrôle des matériaux fissibles soient satisfaites.

. Les solutions techniques nécessaires devront être élaborées en Suède, mais on examinera auparavant les techniques étrangères disponibles.

. Les travaux seront supervisés par les organismes de réglementation et ils devront être menés conformément aux directives émises par ces organismes.

. Les activités relatives à la gestion des déchets seront menées ouvertement et le grand public recevra toute l'information nécessaire (Suède, SKN, 1987b, p. 31-32).

Afin de mieux connaître les conditions d'enfouissement en formations géologiques profondes, le SKB exploite une installation de recherche souterraine pour l'évacuation de déchets de haute activité dans la mine de Stripa, à environ 230 km à l'ouest de Stockholm. Les chercheurs de ce laboratoire élaborent des techniques en vue de concevoir un dépôt final en formation cristalline stable. La mine de Stripa est une ancienne mine de fer. Les travaux sur le programme d'évacuation des déchets ont débuté en 1976, une fois le minerai exploité. Des tunnels ont été creusés à 360 mètres de profondeur, dans une formation de granite à la lisière du filon de minerai. Des expériences de chauffage non radioactif ont été menées dans la mine de Stripa dans le cadre d'un projet conjoint Suède-É.-U. Aujourd'hui, la recherche porte principalement sur la détection et la cartographie des zones de fracture, sur la mesure de l'écoulement des eaux souterraines et de la migration des nucléides ainsi que sur l'utilisation de la bentonite pour le remblayage et le scellement (Suède, SKB, non daté).

Le programme suédois d'évacuation des déchets de haute activité en formations géologiques profondes et stables est comparable aux programmes du Canada et de la Suisse, qualifiés par les Suédois de «matures». Les Suédois considèrent que, dans certains domaines, le Canada est en avance en ce qui concerne les travaux de R et D menés dans le cadre de son programme d'évacuation des déchets.

En plus du programme d'évacuation du combustible épuisé, la Suède dispose d'un excellent système de stockage intermédiaire de tous les déchets radioactifs ainsi que d'un système d'évacuation des déchets de faible activité et d'activité intermédiaire.

Exigences légales pour l'évacuation sûre des déchets radioactifs en Suède

En vertu de la loi suédoise datant de 1976, les entreprises d'énergie électronucléaire ont dû démontrer que le combustible nucléaire épuisé pouvait être manipulé et évacué sans danger avant d'être autorisées à charger du combustible dans de nouveaux réacteurs et à les mettre en service. Les entreprises ont présenté leur premier rapport de recherche à cet effet, le KBS-1, en novembre 1977, ainsi qu'une demande pour charger en combustible les réacteurs Ringhals 3 et Forsmark 1. Les réacteurs Ringhals 4 et Forsmark 2 ont par la suite été ajoutés à cette demande. Dans le KBS-1, on supposait que le combustible épuisé serait retraité, ce qui était alors la solution préférée en Suède. Le rapport KBS-2, préconisant l'évacuation directe du combustible nucléaire sans retraitement, a été présenté en 1978. Ce rapport a été accepté par le gouvernement comme condition de l'approbation du chargement en combustible des quatre réacteurs. En mai 1983, le rapport KBS-3 a été annexé aux demandes visant le chargement en combustible des réacteurs Forsmark 3 et Oskarshamn 3. Le KBS-3 a approfondi et étendu le contenu du KBS-2; en juin 1984, le gouvernement a accordé la permission de chargement en combustible des deux derniers réacteurs suédois. Le gouvernement reconnaissait ainsi que les exigences de la loi avaient été respectées et que les entreprises avaient prouvé qu'il existait une méthode sure d'évacuation du combustible épuisé (Suède, SKB, 1985).

Selon le KBS-3, le combustible épuisé est enfoui dans un dépôt souterrain à 500 mètres de profondeur, dans une formation cristalline stable. Des conteneurs de cuivre seront utilisés pour le stockage du combustible épuisé. Une fois plein, le dépôt sera remblayé et scellé, et il ne nécessitera pas de surveillance subséquente. La sûreté du dépôt «est basée sur le fait que la dégradation des conteneurs et le transport subséquent du contenu par les eaux souterraines vers la surface prendra si longtemps que les substances radioactives se désintégreront et seront diluées de telle façon que lorsqu'elles atteindront la biosphère, les concentrations seront inoffensives» (Suède, SKB, 1985, p. 12). Selon le calendrier fixé par le SKB, le site du dépôt devra être choisi en 1990-1992 et le système de barrière artificielle (c'est-à-dire la construction du dépôt, la forme des déchets radioactifs évacués, la conception du conteneur ainsi que la nature du matériau-tampon et du matériau de remblayage autour des conteneurs) devra être choisi entre 1994 et 1996. La demande d'implantation devra être présentée en l'an 2000, le rapport de sûreté soumis en 2006, la construction du dépôt commencée en 2010 et l'exploitation commencée en 2020. Certains critiques du programme prétendent que ce calendrier ne laisse aucune place à l'imprévu (Suède, SKN, 1987b).

Le programme de gestion des déchets du SKB est fondé sur les principes suivants :

. Les déchets radioactifs produits par les centrales nucléaires suédoises seront évacués en Suède.

. Le combustible nucléaire épuisé sera évacué sans être retraité.

. Les systèmes et installations techniques devront se conformer à des normes élevées de sûreté et de protection contre les rayonnements et ils devront satisfaire les autorités suédoises.

surveillance et l'autorité financière requises pour veiller à ce que ces trois principes soient suivis. La SKN recommande au gouvernement la redevance à percevoir par kilowattheure d'énergie électronucléaire produite en vue de couvrir tous les coûts futurs de gestion et d'évacuation des déchets nucléaires et de déclassement des centrales nucléaires. Cette somme est fixée annuellement et est versée par les entreprises de services publics dans des comptes spéciaux administrés par la SKN. Avant 1981, les entreprises de services publics accumulaient des réserves internes destinées à ces activités; la SKN a pris à sa charge le fonds accumulé lorsque la redevance et les comptes du gouvernement ont été créés. Ce fonds accumule de l'intérêt au taux courant. À mesure que les entreprises dépensent des sommes pour la gestion des déchets ou le déclassement des centrales, la SKN libère des fonds de ce compte pour les rembourser (Forum suédois sur l'énergie atomique, non daté).

Cette loi lance un défi intéressant à la SKN : elle prévoit que les dépenses liées à la gestion des déchets radioactifs et au déclassement des centrales se poursuivront jusque vers 2050 ou 2060, mais la SKN ne pourra recueillir les droits que jusqu'à la mise hors service du dernier réacteur en 2010. Comment l'organisme prévoit-il le coût total d'un programme qui se poursuivra pendant 70 ans ou plus dans le futur? À l'heure actuelle, la SKN ne sait pas ce que sera le calendrier de mise hors service des réacteurs, exception faite des deux réacteurs qui seront mis hors service en 1995 et 1996.

En acceptant le principe de l'évacuation dans des formations géologiques profondes tel que défini dans le modèle KBS-3, le gouvernement suédois s'est créé un problème. En acceptant ce principe, les entreprises d'énergie électronucléaire satisfaisaient à l'exigence légale de mise en marche des nouveaux réacteurs de puissance restants. C'est à partir du modèle KBS-3 que la SKB (Société suédoise de gestion du combustible et des déchets nucléaires appartenant aux entreprises de services publics) a par la suite élaboré son programme de R et D. Le rapport sur le KBS-3 a été terminé en 1983 et bien que la recherche subséquente n'ait pas amené le gouvernement à réévaluer ses conclusions sur la sûreté du modèle KBS-3, la SKN aimerait que la SKB élargisse une partie des activités de R et D, afin de ne pas laisser passer de meilleures solutions techniques. La SKB se retrouve ainsi dans une position où l'organisme gouvernemental qui surveille son programme de R et D lui demande de consacrer plus de temps et d'argent à l'étude de solutions de rechange au modèle d'évacuation KBS-3 que le gouvernement suédois a déjà reconnu comme acceptable.

Le SKI est secondé dans son travail par trois comités consultatifs : le Comité de la sûreté des réacteurs (qui donne des conseils en matière de sûreté des réacteurs et de délivrance de permis), le Comité des mesures de protection (qui donne des conseils en matière de contrôle des matières fissiles et de protection contre le vol et le sabotage des installations nucléaires et des substances nucléaires pendant le transport) et le Comité de la recherche (qui évalue et propose des projets de recherche) (Suède, SKI, non daté).

Le SKI joue en Suède un rôle semblable à celui de la Commission de contrôle de l'énergie atomique au Canada. Le Comité constate que le SKI a un Secrétariat d'information, dont «le rôle premier ... est d'informer le public sur les travaux effectués par le SKI en matière de sûreté nucléaire ... L'information relative aux positions du SKI sur différents aspects de la sûreté nucléaire est destinée aux médias, aux groupes de pression et aux comités de sûreté locaux, de même qu'aux politiciens, aux particuliers et aux sociétés privées» (Suède, SKI, non daté, p. 7). Le Comité recommande à la CCÉA de jouer un plus grand rôle dans ce domaine au Canada.

D'après une résolution du Parlement suédois, chaque réacteur de puissance doit être soumis à au moins trois analyses de sûreté pendant sa durée de vie prévue, en plus des analyses de sûreté effectuées avant sa mise en service. Ces analyses périodiques rassemblent les données d'exploitation du réacteur, les résultats de programmes d'essais appliqués au réacteur et les résultats des travaux suédois et internationaux sur la sûreté des réacteurs.

La Commission nationale suédoise du combustible nucléaire épuisé, la SKN, a été créée en 1981 et elle est l'autorité administrative centrale en vertu de la *Loi modifiée sur le financement des mesures futures d'évacuation du combustible épuisé*. Cette loi a établi trois principes de gestion des déchets nucléaires:

1) Le producteur de déchets nucléaires doit prendre les mesures nécessaires pour leur gestion et leur évacuation.

2) C'est à l'État qu'il incombe en dernier ressort de veiller à ce que les déchets soient évacués d'une façon qui satisfasse le public suédois.

3) Les coûts de la gestion des déchets doivent être défrayés par ceux qui bénéficient de l'énergie électronucléaire. Le capital requis pour les activités de gestion des déchets après exploitation doit par conséquent être recueilli pendant l'exploitation du réacteur et rester disponible pour les besoins futurs (Forum suédois sur l'énergie atomique, non daté, p. 34).

En vertu de la *Loi sur les activités nucléaires* de 1984, à la fonction financière de la SKN s'est ajouté un droit de regard sur la R et D que les entreprises d'énergie électronucléaire effectuent pour la gestion et l'évacuation du combustible nucléaire épuisé et pour le déclassement des centrales nucléaires. La SKN a ainsi l'autorité de

L'Institut national suédois de radioprotection, le SSI, relève du ministère de l'Environnement et de l'Énergie, et il administre la *Loi sur la radioprotection* et l'ordonnance sur la radioprotection. Depuis 1965, le SSI est la plus haute autorité suédoise en matière de radioprotection. L'Institut exploite 25 postes de mesure répartis à la grandeur du pays, où l'on enregistre les niveaux du rayonnement naturel. Il effectue aussi des mesures régulières des doses individuelles reçues par les travailleurs qui utilisent des rayonnements ionisants, et ces mesures portent à l'heure actuelle sur environ 14 000 personnes. En matière d'énergie nucléaire, le SSI réglemente l'émission de radioactivité dans les centrales nucléaires, examine les exigences de radioprotection dans ces installations et fixe les limites de dose pour le personnel. Toutes les activités de transport des substances radioactives sont surveillées par le SSI. Le SSI et l'Administration nationale de sauvetage sont chargés conjointement de la planification des mesures d'urgence en cas d'accident nucléaire (Suède, SSI, 1987).

Le Corps d'inspection de l'énergie nucléaire de la Suède, le SKI, est l'organisme de réglementation établi en vertu de la Loi sur les activités nucléaires. Les tâches principales du SKI sont les suivantes :

. évaluer la conception des installations nucléaires du point de vue de la sûreté;

. formuler des lignes directrices en matière de sûreté et inspecter les installations nucléaires;

. étudier et évaluer le fonctionnement pratique, et prendre des mesures de sûreté;

. inspecter les substances nucléaires et les recenser conformément aux règlements internationaux et suédois afin de prévenir l'utilisation de ces substances à des fins non pacifiques;

. inspecter et préparer des règlements sur la manipulation et le stockage des déchets nucléaires;

. mettre sur pied et diriger la recherche dans le domaine de la sûreté nucléaire;

. informer le public sur les travaux en cours de réalisation en matière de sûreté nucléaire (Forum suédois sur l'énergie atomique, non daté, p. 33).

La responsabilité directe de la sûreté des installations nucléaires revient cependant aux propriétaires, qui doivent respecter toutes les directives émises par le SKI.

davantage de combustibles fossiles pendant encore quelques années, curieuse compensation pour un pays qui a été particulièrement touché par les précipitations acides. La Suède prévoit importer des quantités beaucoup plus grandes de gaz naturel pour remplacer l'électricité de source nucléaire. Il est fort probable que l'Union soviétique fournira la plus grande partie de ce gaz; or, la Suède a souvent accusé les sous-marins soviétiques d'avoir violé ses eaux territoriales. Comme la Suède tient beaucoup à sauvegarder son statut de nation neutre, on s'étonne qu'elle se place ainsi à la merci de l'URSS.

3. Gestion des déchets radioactifs

Le programme de gestion des déchets radioactifs de la Suède est bien organisé et financé. Il est géré par une société créée spécifiquement à cette fin en 1972, la *Svensk Kärnbränslehantering AB*, ou SKB (Société suédoise de gestion du combustible et des déchets nucléaires). La SKB appartient aux quatre services publics d'électricité suédois qui exploitent des réacteurs de puissance : Vattenfall (Commission d'énergie électrique d'état de la Suède) (36 %); Forsmarks Kraftgrupp AB (30 %); OKG Aktiebolag (22 %); et Sydsvenska Värmekraft AB (12 %). La Vattenfall est le plus gros service public d'électricité de la Suède : elle produit près de la moitié de l'électricité du pays et exploite la centrale Ringhals, qui comprend quatre réacteurs. La Forsmarks Kraftgrupp, qui exploite la centrale Forsmark de trois réacteurs, est détenue conjointement par la Vattenfall et un consortium privé. La OKG Aktiebolag est un consortium privé de huit sociétés qui produit 40 % de l'électricité de la Suède et qui exploite la centrale Oskarshamn de trois réacteurs. Le principal actionnaire de la OKG est la Sydkraft AB, la plus grosse société d'électricité privée en Suède, qui possède aussi la Sydsvenska Värmekraft AB et exploite la centrale Barsebäck de deux réacteurs (Suède, SKB, 1985). Le programme d'énergie nucléaire de la Suède regroupe les secteurs public et privé.

La SKB est chargée de concevoir, planifier, construire et exploiter des installations servant à la gestion et à l'évacuation du combustible nucléaire épuisé et d'autres déchets radioactifs produits dans les centrales nucléaires suédoises. Elle est chargée des activités de recherche et de développement en matière de gestion des déchets radioactifs. La SKB s'occupe aussi des questions de prospection du minerai d'uranium, d'enrichissement du combustible, de retraitement du combustible et de stockage de l'uranium pour l'industrie nucléaire de la Suède.

Trois organismes d'état travaillent en étroite collaboration avec la SKB. L'Institut national de radioprotection, le SSI (*Statens stralskyddinstitut*), et le Corps d'inspection de l'énergie nucléaire de la Suède, le SKI (*Statens kärnkraftinspektion*), ont un rôle de régulateur. La Commission nationale du combustible nucléaire épuisé, la SKN (*Statens kärnbränslenämnd*), perçoit les droits des exploitants de réacteurs et administre le fonds du programme.

Tableau 9 : Réacteurs de puissance en service en Suède au 1er janvier 1988

Réacteur / Type	Exploitation commerciale	Puissance électrique nette	Contractant
Oskarshamn 1 / BWR	1972	440 MW	ASEA–ATOM
Oskarshamn 2 / BWR	1975	595 MW	ASEA–ATOM
Oskarshamn 3 / BWR	1985	1 070 MW	ASEA–ATOM
Ringhals 1 / BWR	1976	750 MW	ASEA–ATOM
Ringhals 2 / PWR	1975	800 MW	Westinghouse
Ringhals 3 / PWR	1981	915 MW	Westinghouse
Ringhals 4 / PWR	1983	915 MW	Westinghouse
Barsebäck 1 / BWR	1975	595 MW	ASEA–ATOM
Barsebäck 2 / BWR	1977	580 MW	ASEA–ATOM
Forsmark 1 / BWR	1981	970 MW	ASEA–ATOM
Forsmark 2 / BWR	1981	970 MW	ASEA–ATOM
Forsmark 3 / BWR	1985	1 063 MW	ASEA–ATOM

Source : Suède, Kärnkraftsäkerhet och Utbildning AB, *Summary of Operating Experience at Swedish Nuclear Power Plants 1987*, Stockholm, février 1988, p. 3.

L'alimentation des 12 réacteurs opérationnels du programme nucléaire suédois nécessite l'apport d'environ 1400 tonnes d'uranium chaque année. Environ 90 % de l'uranium est acheté dans le cadre de contrats à long terme. Entre 1983 et 1992, les deux tiers environ de cet uranium proviendront du Canada, le cinquième de l'Australie, et le reste de la France et des États-Unis (Suède, ministère de l'Industrie, 1986). En 1987, le Canada a exporté 377 tonnes d'uranium destinées à la Suède, après enrichissement dans d'autres pays, tandis qu'il en a expédié 449 tonnes en 1986 (Canada, CCÉA, 1988, p. 9). On sait que la Suède a des gisements d'uranium, de qualité commerciale. Mais les Suédois n'extraient pas le minerai, apparamment pour des raisons environnementales.

La situation du nucléaire en Suède est teintée d'ironie. La Suède déclassera certains BWR parmi les plus efficaces au monde, réacteurs qu'une commission suédoise a jugés suffisamment sûrs au cours de leur vie utile, pendant que les Russes continueront d'exploiter des RBMK dont une unité a été à l'origine des retombées radioactives sur la Suède après l'accident de Tchernobyl. Pour compenser la perte d'électricité de source nucléaire, les Suédois reconnaissent qu'il leur faudra consommer

services publics affichaient un solde de 3900 millions Skr (750 millions $CAN). Le coût total estimé du programme est de 38 000 millions Skr (7310 millions $CAN). La dernière année de perception des droits est l'an 2010, mais la majeure partie des dépenses se fera par la suite, la plus grande étant celle qui permettra de réaliser le dépôt permanent.

Certains Suédois doutent que le gouvernement puisse en réalité mettre fin à l'utilisation de l'énergie nucléaire, car il sera difficile de remplacer cette source d'énergie. L'accident survenu à Tchernobyl en mai 1986, et surtout les retombées radioactives, ont renforcé la détermination du gouvernement et durci l'opinion publique. Au moment de la visite du Comité dans ce pays, le *Riksdag* étudiait un projet de loi prévoyant le déclassement de deux réacteurs, un à Barsebäck et l'autre à Ringhals, en 1995 et 1996. Le Comité a appris que ce projet de loi avait été adopté. Le réacteur de Barsebäck appartient à une entreprise privée, la Sydkraft, et n'aura pas atteint la fin de sa durée de vie utile en 1995. Le gouvernement suédois devra donc se pencher sur la question de la compensation financière des exploitants privés dont les réacteurs commenceront à être mis hors service à compter de 1995.

2. Le programme actuel des réacteurs de puissance

La Suède compte 12 réacteurs de puissance en exploitation, d'une puissance nette installée de 9663 MW. Neuf sont des réacteurs BWR conçus et installés par l'ASEA-ATOM (qui fait maintenant partie de l'ASEA/Brown Boveri), et trois sont des réacteurs PWR de la Westinghouse. Ces douze réacteurs font partie de quatre centrales. Trois réacteurs BWR sont situés à Oskarshamn, sur la côte Baltique, à environ 300 kilomètres au sud de Stockholm. Trois réacteurs BWR sont situés à Forsmark, sur la côte, à 150 km au nord de Stockholm. Les deux réacteurs BWR de Barsebäck font face à la capitale danoise, Copenhague. La centrale de Ringhals, située sur la côte ouest à environ 60 km au sud de Göteborg, compte trois réacteurs PWR et un réacteur BWR. Les réacteurs BWR de Suède ont le meilleur facteur de charge annuel moyen, soit 82,5 % au cours de la période de 12 mois s'étant terminée le 30 juin 1987, comparativement aux autres pays exploitant au moins quatre réacteurs de ce type (Howles, 1988, p. 22). Aucun autre réacteur n'est en construction ou planifié en Suède.

La liste des 12 réacteurs de la Suède est donnée au tableau 9. Ensemble, ces réacteurs ont produit 15 % de l'énergie primaire totale du pays en 1986.

En 1985, 42,4 % de l'électricité produite en Suède a été fournie par des centrales nucléaires; en 1986, cette proportion est montée à 50,3 %. La Suède se trouve au troisième rang des pays de l'OCDE, la France venant en tête en 1986 avec 69,8 %, suivie de la Belgique avec 67,0 %.

loi reprend également une exigence qui était devenue loi en 1976, à savoir que pour tout réacteur de puissance chargé de combustible pour la première fois, l'exploitant doit obtenir un permis spécial qui lui est accordé uniquement si :

1. il a prouvé qu'il existe une méthode de manutention et d'élimination définitive du combustible nucléaire épuisé et des déchets radioactifs produits par le réacteur qui soit acceptable du point de vue de la sécurité et de la radioprotection;

2. il a présenté un programme de travaux de recherche et de développement qui garantissent que le combustible nucléaire épuisé provenant du réacteur ainsi que les déchets radioactifs produits peuvent être manutentionnés et éliminés définitivement d'une manière sûre (Suède, ministère de l'Industrie, 1984, p. 4).

Les cinq réacteurs mis en service avant 1976 ne sont pas visés par cette partie de la loi, mais les sept autres le sont. Les compagnies d'électricité ont proposé en conséquence la notion de l'enfouissement des déchets extrêmement radioactifs dans des formations géologiques profondes, notion qui a été acceptée par le gouvernement comme étant une méthode d'élimination sûre.

La *Loi modifiée sur le financement des mesures futures visant l'élimination du combustible épuisé* est également entrée en vigueur en 1984. Cette loi exige que tout exploitant d'un réacteur assume les coûts :

1. de la manutention et de l'élimination définitive en toute sécurité du combustible nucléaire épuisé du réacteur et des déchets radioactifs produits par lui;

2. de la mise hors service et du démontage en toute sécurité du réacteur;

3. des travaux de recherche et de développement nécessaires pour permettre la bonne exécution des mesures dont il est question en 1 et 2 ci-dessus (Suède, ministère de l'Industrie, 1984, p. 11).

Outre les coûts susmentionnés, les exploitants de réacteurs sont tenus par la loi de prendre à leur charge les frais encourus par l'État pour mener des travaux de recherche et de développement complétant ceux des exploitants, certains frais administratifs et autres encourus pour appliquer la loi, ainsi que les frais découlant du contrôle et de l'inspection des dépôts permanents. Les fonds que le gouvernement estime nécessaires à ces fins proviennent d'un droit annuel payé à l'État par les exploitants tant que les réacteurs sont en exploitation. Ces droits sont versés dans des comptes distincts pour chacun des groupes de services publics. Le droit est établi par l'État en fonction de la quantité d'électricité délivrée par les réacteurs. Il est actuellement fixé à 0,019 Skr/kWh (soit environ 0,0037 $CAN/kWh ou encore 3,7 mills/kWh. Le taux de change utilisé est une couronne suédoise = 0,1923 dollar canadien. Les sommes équivalentes en devises canadiennes sont arrondies. Ces droits rapportent la somme de 1200 millions Skr (230 millions de dollars canadiens) annuellement, dont environ 600 millions Skr (115 millions $CAN) sont dépensés chaque année pour couvrir les coûts courants du programme. À la fin de 1987, les comptes de

Des Suédois ayant droit de voter, 75,6 % ont participé au référendum, taux le plus élevé des quatre référendums. Les résultats ont été les suivants :

Solution 1 : 18,9 % Solution 2 : 39,1 % Solution 3 : 38,7 %

Seulement 3,3 % des bulletins ont été annulés.

Devant les résultats du référendum, le gouvernement suédois a annoncé qu'il stoppait le développement du nucléaire, que les réacteurs de puissance alors en construction pourraient être mis en service et que tous les réacteurs de puissance seraient déclassés d'ici l'an 2010. Le gouvernement a décidé qu'il n'était pas possible à ce moment de préciser quand l'élimination graduelle de l'électronucléaire pourrait commencer, mais que l'ordre de déclassement des réacteurs dépendrait de facteurs de sûreté. La construction de réacteurs à des fins de chauffage urbain a également été interdite, ainsi que la construction de surrégénérateurs. La vitesse de l'élimination graduelle de l'électronucléaire devait être fixée en tenant compte du fait que l'électricité est nécessaire à l'emploi et au bien-être national.

En 1985, la politique énergétique décennale étant parvenue à son terme, le gouvernement suédois a rendu public un nouvel énoncé de politique. Cet énoncé a pris la forme d'un projet de loi sur les orientations de la politique énergétique, projet qui a été adopté par le *Riksdag* sans modification majeure. Cette politique réaffirme l'engagement du gouvernement d'abandonner l'énergie nucléaire d'ici l'an 2010, objectif qu'il se propose d'atteindre en favorisant les économies d'énergie, l'utilisation accrue du chauffage urbain, la mise en valeur de nouvelles sources d'énergie et de nouvelles techniques, et la poursuite des travaux de recherche et de développement dans le secteur énergétique. La politique propose également de stabiliser la consommation énergétique suédoise à compter de 1990 environ et de faire en sorte que la Suède soit moins tributaire du pétrole. Le gouvernement résume ainsi sa politique :

> Pour le reste des années 80, le principal objectif de la politique énergétique doit être de parachever la restructuration du système énergétique afin de réduire la part du pétrole et d'augmenter celle des énergies renouvelables et indigènes, tout en créant les conditions permettant d'éliminer graduellement l'énergie nucléaire. Un aspect de cette restructuration est la création d'un système énergétique qui soit moins vulnérable aux perturbations de l'offre internationale et qui se traduise par une amélioration de la sécurité des approvisionnements (Suède, ministère de l'Industrie, 1986, p. 7).

La Loi sur les activités nucléaires est entrée en vigueur en 1984. Cette loi précise les responsabilités de l'État et de l'industrie de l'électricité en ce qui a trait à la sûreté nucléaire. Elle exige que tous les exploitants de réacteurs de puissance établissent collectivement un programme global de recherche et de développement en matière de gestion des déchets nucléaires, notamment leur élimination définitive. Ce programme doit indiquer toutes les mesures à prendre au moins six ans à l'avance. Il doit être présenté au gouvernement tous les trois ans à des fins d'évaluation, à partir de 1986. La

le *Riksdag* décida en conséquence dans sa politique de 1975 de restreindre le développement du nucléaire jusqu'en 1985 en le limitant aux sites actuels et à 13 réacteurs au total. La nouvelle politique énergétique soulignait la nécessité de la liberté action, ce qui, concrètement, voulait dire qu'il fallait trouver d'autres solutions énergétiques (tant pour ce qui était de l'offre que de la demande) de sorte que les Suédois ne soient pas «prisonniers du système énergétique» (Suède, Secrétariat de prospective, 1977, p. 15).

L'accident survenu en mars 1979 à l'unité 2 de la centrale nucléaire de Three Mile Island, en Pennsylvanie, eut un impact considérable sur l'opinion publique suédoise. En 1980, le gouvernement suédois organisa un référendum consultatif sur l'avenir du nucléaire en Suède; il s'agissait du quatrième référendum public tenu dans ce pays. Le référendum proposait trois solutions, aucune ne proposant le maintien du nucléaire. En voici le texte (traduction libre en français).

Solution 1 : L'énergie nucléaire sera graduellement éliminée, à une vitesse qui ne compromettra pas la production de l'électricité nécessaire au maintien de l'emploi et de la prospérité. Afin, notamment, d'être moins tributaire du pétrole et sous réserve de la disponibilité de sources d'énergie renouvelable, le pays n'exploitera que les 12 réacteurs nucléaires déjà en exploitation, prêts à entrer en service ou en construction. Il n'y aura pas expansion du secteur de l'énergie nucléaire. L'ordre dans lequel les réacteurs seront mis hors service sera fonction de facteurs de sécurité.

Solution 2 : [Comprend la Solution 1, plus le texte qui suit imprimé au verso du bulletin de vote] Le pays veillera par tous les moyens à économiser l'énergie et incitera davantage les citoyens à le faire. Les groupes les plus défavorisés de la société seront protégés. On prendra des mesures pour rationaliser la consommation d'électricité dans le but, notamment, de doter tous les nouveaux immeubles permanents de chauffage électrique à action directe préventive. Des fonds publics seront utilisés pour accélérer les travaux de recherche et de développement portant sur les sources d'énergie renouvelable. Des mesures pour améliorer les normes environnementales seront prises dans les centrales nucléaires. Une étude spéciale de sûreté sera effectuée pour chacun des réacteurs. Un comité de sûreté, composé notamment de représentants locaux, sera nommé pour chacune des centrales nucléaires pour surveiller l'exploitation de ces dernières par le public. On évitera de produire de l'électricité par condensation de vapeur produite par combustion de pétrole et de charbon (génération thermique). Ce sont des organes publics qui seront principalement chargés de la production et de la distribution de l'énergie électrique. Les centrales nucléaires et toute autre installation future d'importance servant à la production d'électricité devront appartenir à des organismes nationaux et locaux. Les profits exceptionnels résultant de la production hydro-électrique seront confisqués par le fisc.

Solution 3 : Il n'y aura pas d'expansion de l'énergie nucléaire. Dans au plus 10 ans, six des réacteurs maintenant en service seront fermés. Pour être moins tributaire du pétrole, on intensifiera les économies d'énergie et on s'efforcera de mettre en valeur des sources d'énergie renouvelable. Des normes de sûreté plus strictes seront imposées sur les réacteurs en exploitation. Aucun réacteur non actif ne sera mis en service. Toute extraction d'uranium sera interdite en Suède. Si les analyses de sûreté actuelles et futures le nécessitent, les réacteurs seront immédiatement fermés. La campagne contre les armements nucléaires et leur prolifération se poursuivra. Aucun retraitement du combustible nucléaire ne sera permis. Les exportations de réacteurs et de technologie nucléaire cesseront. L'emploi sera stimulé par la production d'autres formes d'énergie et par un traitement plus poussé des matières premières.

B. Le programme électronucléaire suédois

1. L'évolution du nucléaire en Suède

D'une superficie de 450 000 kilomètres carrés (174 000 milles carrés), la Suède est le quatrième pays d'Europe, mais sa population est inférieure à 8,4 millions de personnes. Plus de 85 % de sa population vit dans la moitié sud du pays. Stockholm compte presque 1,5 million d'habitants.

Au cours de la Deuxième Guerre mondiale, le blocus du trafic maritime mis en place dans l'Atlantique par les sous-marins allemands a montré qu'il était dangereux de dépendre de combustibles importés. Lorsque les importations de pétrole ont repris en Suède après la guerre, certains se sont alarmés. La mise en place d'un programme électronucléaire suédois dans les années 50 a été motivée en partie par le désir de restreindre ces importations. Contrairement à la plupart des pays, la Suède a d'abord envisagé de se servir du nucléaire essentiellement pour le chauffage urbain. Un réacteur (Agesta, réacteur d'une puissance de 60 MWt augmentée par la suite de 20 MWe) fut construit à cette fin, sous terre, dans la ville de Stockholm; il fut démonté au milieu des années 70. Les Suédois ont ensuite utilisé des réacteurs nucléaires pour produire à la fois de l'électricité et de la chaleur (cogénération). Lors d'une décision critique prise dans les années 60, une centrale nucléaire de cogénération planifiée pour la cité de Västeras a été annulée et remplacée par une centrale au pétrole. Comme la production d'électricité et sa distribution sont des fonctions distinctes en Suède (en 1946, l'Office étatique de l'énergie a reçu le droit exclusif de construire et d'exploiter le réseau de distribution), la mesure portait un sérieux coup aux producteurs qui favorisaient l'expansion de l'électronucléaire. Par la suite, l'accent a été mis sur la production d'électricité nucléaire dans de grandes centrales centralisées, tandis que certaines municipalités construisaient leurs propres centrales de cogénération alimentées au pétrole (Suède, Secrétariat de prospective, 1977). Avant les années 70, pour les Suédois une «bonne» politique énergétique était essentiellement une politique qui permettait d'offrir à l'ensemble de la collectivité de l'énergie au meilleur prix possible.

Au moment de l'embargo pétrolier décrété par les nations arabes, la Suède dépendait de pétrole importé pour 73 % environ de ses besoins d'énergie primaire. En 1975, le Parlement suédois (*Riksdag*) adopta une politique énergétique dans le but de façonner le développement énergétique jusqu'en 1985. Un des grands axes de cette politique était de se réserver toute une gamme de possibilités énergétiques. Un but de la politique était de ramener la croissance annuelle de la demande énergétique de 4,5 % à 2 %. Cette réduction n'a pas été perçue comme une fin en soi, mais bien comme un moyen de réduire les importations de pétrole, de restreindre la croissance de la production de l'électronucléaire et de ralentir le développement de l'hydro-électricité. L'utilisation continue de l'énergie nucléaire faisait alors l'objet d'un vigoureux débat et

La source utilisée pour compiler le tableau 8 n'indiquait pas la moyenne mondiale de la consommation d'électricité par habitant; celle-ci a donc été calculée à partir du pourcentage de la consommation de chaque pays par rapport à la consommation mondiale.

Tableau 8 : Consommation d'électricité par habitant dans certaines nations, en 1985

Pays	kWh/Person	% de la consommation moyenne mondiale
Norvège	21 950	1 127 %
Canada	**16 485**	**846 %**
Islande	15 833	813 %
Suède	15 661	804 %
Qatar	11 415	586 %
Luxembourg	10 811	555 %
Finlande	9 998	513 %
États-Unis	9 652	496 %
Nouvelle-Zélande	8 708	447 %
Australie	7 727	397 %
Allemagne de l'Est	6 839	351 %
Allemagne de l'Ouest	5 666	291 %
URSS	5 450	280 %
France	5 072	260 %
Japon	4 440	228 %
Afrique du Sud	4 356	223 %
Royaume-Uni	4 157	213 %
Moyenne mondiale	**1 950**	**100 %**
Brésil	1 316	68 %
Mexique	1 177	60 %
Égypte	474	24 %
Chine	359	18 %
Inde	165	8 %
Nigeria	61	3 %

Note : La moyenne mondiale a été calculée approximativement à partir du pourcentage de la consommation de certains pays.

Source : Canada, ÉACL, *Coup d'oeil sur le nucléaire*, Affaires publiques du bureau central, septembre 1987, p. C-12.

Tableau 7 : Nombre cumulatif de commandes de réacteur par fournisseur à la fin de 1986

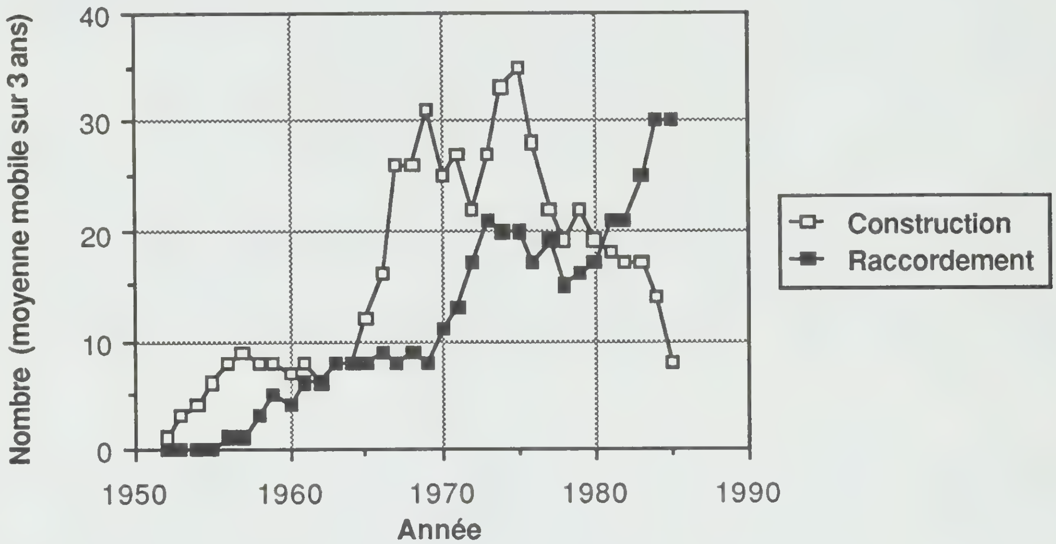
Fournisseur	Nombre de réacteurs	Capacité de production (GWe)	Pourcentage de la capacité de production totale
Westinghouse	85	77,4	17,8 %
Framatome	65	71,1	16,4 %
URSS (besoins nationaux)	93	69,6	16,0 %
General Electric	62	52,0	12,0 %
Kraftwerk Union	26	27,8	6,4 %
Énergie atomique du Canada, Limitée	**31**	**21,4**	**4,9 %**
Royaume-Uni	43	15,5	3,6 %
Mitsubishi Heavy Industries	18	15,0	3,5 %
Combustion Engineering	15	14,8	3,4 %
URSS (exportation/Atomenergoexport)	29	14,6	3,4 %
Babcock & Wilcox	11	10,5	2,4 %
Toshiba	10	9,0	2,1 %
Skoda	15	8,7	2,0 %
ASEA-ATOM	11	8,7	2,0 %
Hitachi	6	5,4	1,2 %
Départ. de l'énergie atomique, Inde	10	2,3	0,5 %
Ansaldo	3	2,0	0,5 %
Divers	25	8,6	2,0 %
Totaux	**558**	**434,4**	**100,0 %**

Source : Nuclear Engineering International, "Reactor Statistics", *World Nuclear Industry Handbook 1988*, Reed Business Publishing, Sutton, Angleterre, 1988, p. 15.

Ce qui frappe au tableau 8 est l'énorme variation de la consommation d'électricité par habitant. Ainsi, toujours par habitant, les Canadiens consomment 270 fois plus d'électricité que les Nigériens. L'écart de consommation d'électricité est donc immense entre les pays industrialisés et les pays en voie de développement. Ceci prouve que la demande d'électricité dans les pays du Tiers monde peut croître considérablement, avec toutes ses conséquences que cela implique.

exempt de toute annulation. Les fournisseurs sont énumérés dans l'ordre décroissant de la capacité de production que représentent les commandes reçues, et non par le nombre de réacteurs commandés.

Graphique 9 : Nombre annuel mondial de mises en chantier de réacteurs et de raccordements à un réseau, 1952-1985 (moyenne mobile sur 3 ans)



Note : Les données variant considérablement, le graphique est en fait celui d'une moyenne mobile sur 3 ans. Le but du graphique est de montrer les tendances, plutôt que les valeurs annuelles.

Source : Adapté de Canada, ÉACL, *Coup d'oeil sur le nucléaire*, Affaires publiques du bureau central, Ottawa, septembre 1987, p. D-17.

Les statistiques de la consommation par habitant révèlent la variation de la demande d'électricité dans le monde. Le tableau 8 présente la consommation par habitant d'électricité dans 23 pays, en 1985. Il y a lieu de souligner que les quatre premières nations sont des pays nordiques et que deux d'entre elles, le Canada et la Suède, ont des programmes d'électronucléaire bien établis.

Le ralentissement de la croissance de la capacité de production de l'électronucléaire au cours du reste du siècle reflète le déclin mondial des mises en chantier de réacteurs survenu au milieu des années 70, étant donné le temps qui s'écoule entre le début de la construction d'un réacteur et son raccordement au réseau. Les mises en chantier ont atteint un sommet en 1975, la construction de 40 réacteurs ayant été amorcée cette année-là. En 1986, un seul nouveau réacteur a été mis en chantier. La situation n'est guère encourageante pour ceux qui vivent de la vente des réacteurs de puissance. Ces fournisseurs, que le Comité a rencontrés, rationalisent leurs opérations et sont en train de voir comment ils pourront survivre au cours des prochaines années, pendant lesquelles les nouvelles commandes seront plutôt rares. Ces fournisseurs prévoient par contre qu'il y aura une reprise des mises en chantier au début du prochain siècle, en raison du déclin de l'offre de pétrole brut léger classique et des problèmes environnementaux que causent les combustibles fossiles.

Le graphique 9 présente deux ensembles de données : les mises en chantier de réacteurs et le nombre de raccordements de réacteurs à un réseau. Les deux ensembles de données sont en fait présentés comme une moyenne mobile sur trois ans, les données variant trop d'une année à l'autre. Les mises en chantier ont atteint un sommet en 1975, et les raccordements au réseau en 1984-1985, ce qui laisse entendre qu'il faut en moyenne 10 ans entre le début de la construction d'un réacteur et son exploitation commerciale.

Une autre caractéristique du développement mondial du nucléaire est le déplacement des mises en chantier de réacteurs des pays industrialisés de l'Occident vers les pays du bloc communiste et du Tiers monde. Ces pays ne représentaient en 1985 que 15,9 % de la capacité de production électronucléaire, mais on prévoit que ce chiffre atteindra 27,9 % en l'an 2000 (Canada, ÉACL, 1987, p. D-10; NEI, 1988, p. 11). D'ici la fin du siècle, la capacité de production électronucléaire dans les systèmes de production de l'Inde, du Brésil, de la Bulgarie, de la Tchécoslovaquie et de l'Union soviétique devrait être de deux à cinq fois plus grande qu'elle ne l'était en 1987 (NEI, 1988, p. 11).

Au cours de 1986, le fournisseur de réacteurs qui s'est le mieux tiré d'affaire, à l'extérieur du bloc communiste, est la société Westinghouse qui a reçu 85 commandes pour ses réacteurs PWR, ce qui représente 15,2 % du total mondial de commandes qui était de 558 (sans compter les annulations). Framatome vient au deuxième rang avec 65 commandes (11,6 %) et la General Electric, au troisième rang, avec 62 commandes (11,1 %). L'ÉACL a reçu plus de commandes (31 commandes 5,6 %) que la Kraftwerk Union (26 commandes, 4,7 %), mais la capacité des réacteurs commandés de cette dernière est supérieure. L'URSS avait prévu construire 93 réacteurs, soit 16,7 % du total mondial, et a reçu des commandes à l'exportation pour 29 autres réacteurs (5,2 %). Le tableau 7 donne plus de détails sur le total cumulatif de commandes par fournisseur,

L'énergie nucléaire présente d'énormes possibilités, et elle a d'abord servi à produire de l'électricité. L'électronucléaire comporte de nombreux avantages uniques, comme la capacité de produire d'énormes quantités d'énergie à partir d'une petite quantité de combustible, un coût de production peu élevé et stable, et une caractéristique de stockage du combustible qui permet de surmonter les interruptions d'approvisionnement en combustible. Aujourd'hui, l'électricité de source nucléaire, de même que le pétrole et le gaz naturel, jouent un rôle majeur comme énergies de remplacement du pétrole. Le développement de l'électronucléaire dans les pays industrialisés diminue la demande de pétrole et contribue à détendre la situation de l'offre et de la demande d'énergie dans le monde.

Des problèmes environnementaux à l'échelle mondiale tels que les précipitations acides et l'effet de serre qu'engendre la concentration croissante de gaz carbonique dans l'atmosphère ont suscité une profonde inquiétude au cours des dernières années. Par ailleurs, l'électronucléaire a des conséquences moins graves sur l'environnement et a l'avantage unique de réduire la somme totale de polluants émis dans l'atmosphère.

En outre, le développement de l'électronucléaire permet aussi d'utiliser les ressources énergétiques limitées et précieuses que sont les combustibles fossiles à d'autres applications ayant une meilleure plus-value (Japon, C.E.A., 1987, p. 12).

La plupart des pays de l'Europe de l'Est se sont également dotés de programmes d'électronucléaire. En 1986, les quatre réacteurs de la Bulgarie ont produit 30 % de son électricité. La Tchécoslovaquie possède sept réacteurs qui ont produit 21 % de son électricité, tandis que les trois réacteurs de la Hongrie ont compté pour 18 % et les cinq de l'Allemagne de l'Est, pour 12 %. Les réacteurs de puissance soviétiques ont produit 11 % de l'électricité produite en URSS au cours de 1986.

Par ailleurs, 24 réacteurs de puissance commerciaux étaient exploités dans six pays en voie de développement à la fin de juillet 1987. Il s'agit de la Corée du Sud, de Taïwan, de l'Argentine, de l'Inde, du Pakistan et du Brésil. Taïwan, avec six réacteurs, et la Corée du Sud, avec sept réacteurs, ont produit environ 44 % de leur électricité en 1986 à partir de la fission.

Il est difficile de prévoir le développement du nucléaire mondial autrement qu'en se basant sur les réacteurs en construction. Les prévisions d'augmentation de la capacité de production faites dans les années 60 et au début des années 70 ont dû être substantiellement réduites lorsqu'il fut apparent que le ralentissement de la croissance de la demande mondiale d'énergie consécutivement aux «crises du pétrole» de 1973-1974 et de 1979-1980 n'était pas un phénomène passager. Il est manifeste, toutefois, qu'au cours des prochaines quinze années au moins l'expansion de l'électronucléaire ralentira considérablement. La *Nuclear Engineering International* fournit les projections qui suivent de la capacité de production de l'électronucléaire dans son plus récent *Handbook* (1988, p. 11) :

1985 : 251,4 GWe (valeur réelle)	1990 : 375,7 GWe
1995 : 435,7 GWe	2000 : 448,5 GWe

C'est aux États-Unis qu'on trouve le plus grand nombre de réacteurs exploitables (109 en juillet 1987). L'Union soviétique suit avec 57 et la France avec 49. Le Royaume-Uni se classe quatrième, avec 38 réacteurs en exploitation, le Japon, cinquième, avec 37, et l'Allemagne de l'Ouest, sixième, avec 21. Le Canada exploite 19 réacteurs et la Suède, qui vient au huitième rang, en a 12. Le tableau 6 donne la liste des 26 pays possédant des réacteurs de puissance exploitables à la fin de juillet 1987. On y inclut les réacteurs de puissance en construction, ce qui permet de constater que cinq autres pays joindront bientôt les rangs des producteurs d'électricité nucléaire.

Au sein de l'OCDE, la proportion de l'électronucléaire dépasse de 16 % la moyenne mondiale et atteint presque 22 % de toute l'électricité produite au cours de 1986. Cette moyenne, toutefois, masque une réalité extrêmement variable. La France a produit 69,8 % de son électricité dans des centrales nucléaires en 1986, tandis que la Turquie n'a pas du tout recours au nucléaire. La Belgique vient au second rang, ayant produit 67 % de son électricité à partir de huit réacteurs. La Suède est troisième, à 50,3 %, et la Suisse, quatrième, à 39,2 %. En comparaison, le Canada a produit 15,1 % de son électricité en 1986 à partir de centrales nucléaires et les États-Unis, 16,6 %. Au sein du Canada, l'électronucléaire a représenté 46 %, 43 % et 3 % de l'électricité produite respectivement en 1986 en Ontario, au Nouveau-Brunswick et au Québec.

Le Japon se distingue par son engagement nucléaire hautement organisé, à long terme. Comme le Japon doit importer la plus grande partie de son énergie, cela n'est pas surprenant du point de vue stratégique : en 1985, le Japon a importé 80,5 % de ses approvisionnements en énergie primaire et 99,7 % de ses approvisionnements en pétrole. Pendant l'embargo des États arabes sur le pétrole, 77,6 % des approvisionnements en énergie primaire ont consisté de pétrole importé; à peine 0,6 % a consisté d'électricité de source nucléaire. En 1986, les importations de pétrole ont chuté à 56,8 % des approvisionnements en énergie primaire, et la proportion de l'électricité de source nucléaire a augmenté à 9,5 % (Japon, Centre de localisation industrielle, 1988).

En juillet 1987, 37 réacteurs de puissance, soit 28 146 MW de puissance installée, étaient exploitables au Japon. Onze unités totalisant 10 068 MW étaient en construction. En 1986, 24,7 % de l'électricité du Japon a été produite par des unités nucléaires (NEI, 1988). Le programme de développement de l'électronucléaire prévoit une puissance nucléaire installée de 53 000 MW en l'an 2000 et de 100 000 MW en l'an 2030. La part prévue de l'électronucléaire dans les approvisionnements totaux en électricité du Japon passera à 40 % en l'an 2000 et à 60 % en l'an 2030. Les réacteurs surrégénérateurs rapides constitueront la principale source d'énergie nucléaire au Japon au cours du siècle prochain (Japon, C.É.A., 1987).

Les raisons invoquées par le Japon pour exploiter l'énergie atomique, malgré les événements tragiques de la Seconde Guerre mondiale, ressortent de cet extrait d'un rapport de la Commission japonaise de l'énergie atomique.

Tableau 6 : Réacteurs de puissance en exploitation ou en construction dans le monde, au 31 juillet 1987

Pays	Réacteurs exploitables		Réacteurs en construction	
	Nombre	MWe	Nombre	MWe
Afrique du Sud	2	1 930	0	0
Allemagne de l'Est	5	1 835	6	2 640
Allemagne de l'Ouest	21	19 911	4	4 325
Argentine	2	1 005	1	745
Belgique	8	5 740	0	0
Brésil	1	657	2	2 618
Bulgaria	4	1 760	4	4 000
Canada	**19**	**12 553**	**4**	**3 740**
Chine	0	0	3	2 172
Corée du Sud	7	5 816	2	1 900
Cuba	0	0	2	880
Espagne	8	5 810	2	2 022
États-Unis	109	100 323	13	15 809
Finlande	4	2 400	0	0
France	49	46 693	14	18 477
Hongrie	3	1 320	1	440
Inde	7	1 243	6	1 410
Italie	3	1 312	3	2 058
Japon	37	28 146	11	10 068
Mexique	0	0	2	1 350
Pakistan	1	137	0	0
Pays-Bas	2	540	0	0
Pologne	0	0	2	930
Roumanie	0	0	5	3 395
Royaume-Uni	38	12 796	5	3 822
Suède	12	10 030	0	0
Suisse	5	3 065	0	0
Taïwan	6	5 144	0	0
Tchéchoslovaquie	7	3 002	9	6 216
URSS	57	34 334	29	29 620
Yougoslavie	1	664	0	0
Totaux mondiaux	**418**	**308 166**	**130**	**118 637**

Source : Nuclear Engineering International, "Reactor Statistics", *World Nuclear Industry Handbook 1988*, Reed Business Publishing, Sutton, Angleterre, 1988, p. 10.

LE DÉVELOPPEMENT DU NUCLÉAIRE DANS LE MONDE

Le Comité a choisi quatre pays étrangers dont il a étudié les programmes nucléaires afin d'élargir la perspective de son étude de la situation canadienne. Les quatre pays choisis sont la Suède, l'Allemagne de l'Ouest, la France et les États-Unis, que le Comité a visités dans cet ordre. Dans tous les cas, des représentants de ces pays ont collaboré sans réserve à transmettre le plus de renseignements et de connaissances possibles dans le peu de temps dont disposait le Comité dans chacun des pays.

Les quatre pays ont une vaste expérience dans le domaine du nucléaire. La Suède a annoncé son intention d'éliminer graduellement l'électronucléaire d'ici l'an 2010, le premier de ses douze réacteurs devant être mis hors service en 1995. À l'autre extrême, la France produit une plus grande part de son électricité à partir de la fission (soit environ 70 % en 1987) que tout autre pays et se sert de certains de ses réacteurs pour répondre aux variations de la demande (suivi de la charge). L'Allemagne de l'Ouest a pour sa part éprouvé des difficultés dans son programme nucléaire. La mise en service du surrégénérateur de 300 MW de Kalkar est retardée par le refus du gouvernement local de délivrer une licence d'exploitation et le récent scandale nucléaire de Hanau a considérablement nui à l'image publique du programme nucléaire de l'Allemagne de l'Ouest. Ce pays est néanmoins sur le point de parachever la première phase de l'intégration de l'électronucléaire à son système énergétique national. Quant aux États-Unis, ils éprouvent énormément de difficultés à poursuivre le développement du nucléaire et le rôle futur de la fission est remis en question.

Avant de passer à l'examen détaillé de la situation de ces quatre pays, le Comité fait un rapide survol du développement du nucléaire dans le monde. Ce survol servira de toile de fond et permettra de mieux évaluer les programmes nucléaires de chacun des pays visités.

A. Perspective internationale

Au 31 juillet 1987, on comptait 418 réacteurs exploitables répartis entre 26 pays. La capacité de production totale de ces réacteurs était de 308 166 mégawatts (308,2 gigawatts). Cent trente réacteurs étaient en construction (NEI, 1988, p. 10). En 1986, la production combinée de tous les réacteurs de puissance représentait environ 16 % de toute l'électricité produite dans le monde.

moteurs d'aviation civils et militaires, bien que sa gamme d'application possible soit plus vaste. La section SENSYS travaille également à la mise au point d'autres types de capteurs.

Les Laboratoires nucléaires de Chalk River et la société Inco Limitée se sont associés pour produire un appareil original, la sonde de forage acoustique. Cette sonde, qui ressemble à une corne de taureau, est utilisée pour mesurer la profondeur des trous de forage et pour détecter la présence de blocages et de fissures le long du trou. La sonde est alimentée par une batterie et elle peut être utilisée dans n'importe quel trou de 4 à 10 pouces de diamètre et de 30 à 400 pieds de profondeur. Elle permet de déterminer si le trou est bloqué ou ouvert. Elle sera principalement utilisée pour placer les charges explosives avec une grande précision afin d'améliorer le dynamitage dans les mines (Canada, ÉACL, Société de recherche, non daté).

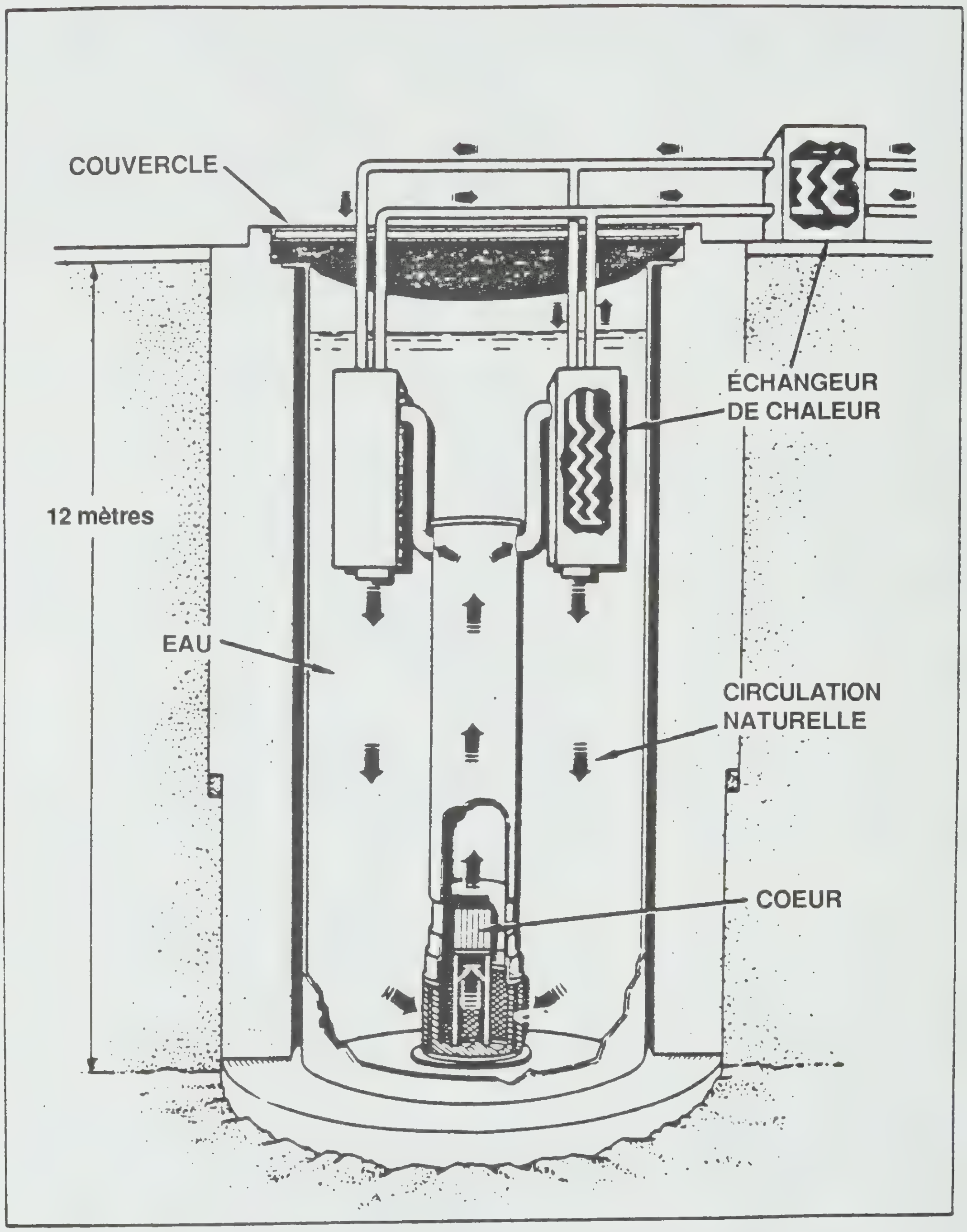
Les Laboratoires nucléaires de Chalk River ont aussi mis au point une gamme de sondes à courants de Foucault ordinaires et spéciales pour la détection des défauts dans les tubes métalliques. Chalk River offre des sondes fabriquées sur mesure aux utilisateurs qui ont des problèmes d'inspection particuliers (Canada, ÉACL, Société de recherche, 1987b).

La Société de recherche a mis au point une technologie des joints de pompe hautement performante et fiable qui trouve maintenant des applications dans le programme spatial américain. L'accident de Challenger en 1986 a été attribué à la défaillance de deux joints toriques sur le moteur d'appoint à poudre qui propulse la navette dans l'espace. Les joints toriques, fabriqués en caoutchouc synthétique, ont pour objet d'empêcher les gaz chauds de la fusée de s'échapper par les joints entre les segments des moteurs d'appoint. La société Morton Thiokol Inc. des États-Unis, maître d'oeuvre pour les moteurs d'appoint à poudre de la NASA, a signé un contrat avec l'ÉACL qui lui permettra de profiter de la compétence de la société en matière de joints d'étanchéité. La capacité de l'ÉACL de réunir une équipe multidisciplinaire pour travailler sur le problème a joué un rôle important dans l'attribution du contrat aux Laboratoires nucléaires de Chalk River. (Canada, ÉACL, Société de recherche, 1987b).

L'étude du lien entre la prédisposition au cancer et des anomalies du métabolisme de l'ADN constitue un domaine de recherche particulièrement intéressant qui est exploré aux Laboratoires nucléaires de Chalk River. On pense que la plupart des tumeurs humaines sont dues en partie à des facteurs environnementaux, facteurs sur lesquels une personne pourrait exercer un certain contrôle. Le principe «à exposition égale, risque égal» suppose une réponse homogène des individus aux agents qui causent le cancer. Toutefois, il est de plus en plus évident qu'il existe des sous-groupes dans la population humaine qui présentent une sensibilité anormale à des agents carcinogènes spécifiques. La capacité variable des individus de réparer des lésions à l'ADN et de rétablir une structure et un fonctionnement normaux de l'ADN semblent jouer un rôle déterminant dans la réaction de ces individus à différents agents carcinogènes. Les chercheurs de Chalk River essaient de mettre au point des tests qui pourraient être utilisés pour le dépistage des personnes à risque élevé. Par exemple, une personne anormalement sensible aux effets des rayonnements ne devrait pas être employée dans un environnement où elle serait exposée à des niveaux élevés de radioactivité. De même, une personne prédisposée aux cancers causés par une exposition excessive à la lumière solaire devrait éviter certaines activités extérieures. Une telle connaissance pourrait servir à élaborer de meilleures stratégies de protection de la santé, spécialement dans le domaine de la santé au travail (Genther et Morrison, 1987).

La section commerciale SENSYS de l'ÉACL, située à Nepean, en Ontario, a mis au point un capteur intelligent appelé Ferroscan. Ce capteur, qui fonctionne en direct et en temps réel, contrôle l'accumulation des débris d'usure du fer dans les systèmes lubrifiés à l'huile. Raccordés en groupes et pilotés par un logiciel approprié, les capteurs Ferroscan permettent à l'utilisateur de suivre l'évolution de l'état des équipements, de planifier des programmes précis d'entretien et de comparer la performance des unités en exploitation. En contrôlant la vitesse et le degré d'usure des éléments lubrifiés à l'huile, le capteur détecte les indices précurseurs de pannes. Contrairement aux autres capteurs, le Ferroscan fonctionne fidèlement dans les systèmes huile-air contenant jusqu'à 90 % d'air. Le capteur est d'application prometteuse dans les

Graphique 8 : La filière énergétique SLOWPOKE



Source : Lynch, G.F., *SLOWPOKE Energy System: Nuclear Technology in Local Energy Supply*, Local Energy Systems Business Unit, Établissement de recherches nucléaires de Whiteshell, ÉACL, Pinawa (Manitoba), février 1988, p. 5.

SLOWPOKE fonctionnent avec un combustible très enrichi (93 % d'uranium 235); le huitième et plus récent est alimenté avec un combustible contenant 20 % d'uranium 235. Tous les réacteurs de recherche SLOWPOKE futurs seront alimentés avec l'uranium moins enrichi (Lynch *et coll.*, 1986).

Dans les pays tempérés, plus de 25 % de l'énergie primaire est consommée pour le chauffage des bâtiments. L'ÉACL a mis au point la filière énergétique SLOWPOKE pour le chauffage urbain, avec une source de chaleur de 10 MWt. Le réacteur SLOWPOKE a les mêmes caractéristiques techniques principales que le réacteur de recherche, plus petit : il fonctionne sous pression atmosphérique, sans cuve sous pression; le transport de la chaleur se fait par refroidissement convectif naturel, sans pompe; le coeur du réacteur est entouré d'un réflecteur en béryllium pour conserver les neutrons; le réacteur est contrôlé à distance et ne requiert pas d'opérateur sur place; enfin, la conception est intrinsèquement sûre. Une sûreté intrinsèque signifie que la protection radiologique est assurée par les caractéristiques inhérentes du réacteur et qu'elle ne dépend pas de systèmes de sûreté incorporés à la construction ou de l'intervention d'un opérateur. Le réacteur possède un coefficient de réactivité négatif, ce qui limite les transitoires de puissance si la régulation du réacteur fait défaut. Une double enceinte de confinement, constituée d'un revêtement en acier et d'une voûte en béton, empêche les accidents de perte de fluide caloporteur. Un espace rempli d'air entre les deux enveloppes est contrôlé de façon à permettre de détecter les fuites de fluide caloporteur. Une plaque d'acier au-dessus du réacteur arrête tous les gaz radioactifs qui s'échappent de la piscine. La filière énergétique SLOWPOKE fonctionne avec de l'uranium enrichi à 4,9 % d'uranium 235, contenu dans 16 grappes de combustible. En supposant un facteur de charge de 50 %, le combustible doit être remplacé tous les six ans (Lynch *et coll.*, 1986).

Une installation de démonstration de 2 MWt a été construite aux Établissements de recherches nucléaires de Whiteshell. Cette installation sera exploitée pour valider la conception. L'ÉACL soutient que la filière énergétique SLOWPOKE devrait pouvoir concurrencer les systèmes de chauffage classiques dans la plupart des régions du Canada. L'ÉACL calcule que le coût de la chaleur fournie peut être aussi bas que 1,2 cent/kWh; une installation de 10 MWt fonctionnant avec un facteur de charge de 40 % fournirait de la chaleur au coût d'environ 2 cents/kWh. Ce prix est concurrentiel par rapport au système à l'huile avec un prix du pétrole aussi bas que 15 $CAN le baril. La simplicité de la filière énergétique SLOWPOKE, avec l'élimination des systèmes sous pression, et la rapidité de la construction (environ un an selon les estimations) sont les principaux facteurs qui contribuent au faible coût d'investissement (Lynch, 1987).

La filière énergétique SLOWPOKE est mise au point à l'Unité des systèmes d'énergie locaux de la Société de recherche de l'Énergie Atomique du Canada, Limitée, aux Laboratoires nucléaires de Chalk River. Des études de faisabilité conjointes entre l'ÉACL et la Corée du Sud, la Chine et la Hongrie ont débuté; la Turquie, la Roumanie et la Yougoslavie se sont montrées intéressées par le principe.

Les applications médicales de la radioactivité se sont considérablement étendues ces dernières années et l'utilisation des radioisotopes à des fins industrielles a aussi connu une forte croissance. Les nouveaux domaines d'application qui font encore l'objet de controverses constituent des créneaux importants pour l'ÉACL ou ses descendants. L'irradiation des aliments est une application de la technologie des radioisotopes qui a suscité un débat récent, bien qu'il soit évident que de nouvelles méthodes sont nécessaires pour réduire les pertes lors du stockage des aliments, surtout dans les pays en voie de développement.

On connaît moins l'utilisation de la radioactivité pour traiter les eaux usées et les boues d'égoût afin de détruire les éléments pathogènes qui rendent ces eaux dangereuses pour les êtres humains. Le Comité espère que le Canada jouera un rôle important dans ces applications bénéfiques de la radioactivité, comme il l'a fait en radiothérapie.

D. Retombées technologiques

Le Comité n'a pas pu mener une étude exhaustive des nouvelles technologies qui ont vu le jour grâce au programme d'énergie nucléaire du Canada. Toutefois, certains membres ont pu observer des exemples de retombées technologiques et ils ont pu se rendre compte que les normes d'assurance de la qualité élaborées par les fournisseurs d'énergie nucléaire ont profité à l'industrie canadienne en général. Plusieurs de ces technologies et leurs applications sont décrites brièvement dans la présente section.

Lors de ses visites aux Laboratoires nucléaires de Chalk River, au laboratoire de l'ÉACL à Ottawa, aux installations CANDU à Mississauga et dans plusieurs entreprises privées choisies en Ontario, le Comité a été impressionné par les retombées moins visibles, mais de grande valeur, du programme nucléaire canadien. Ces activités, dont un grand nombre n'ont rien à voir avec le nucléaire, seraient aussi mises en péril si le programme de l'énergie nucléaire devait être abandonné.

La filière énergétique SLOWPOKE est un système de production et de distribution de la chaleur basé sur le réacteur thermique SLOWPOKE. Le réacteur SLOWPOKE initial a été mis au point en 1968-1969 aux Laboratoires nucléaires de Chalk River. C'était un réacteur thermique de type piscine de 20 kilowatts. L'exploitation du prototype a commencé en 1970 et huit réacteurs additionnels ont ensuite été mis en service. Ces réacteurs de recherche SLOWPOKE sont installés un peu partout : Université de Toronto, École polytechnique, Université Dalhousie, Université de l'Alberta, Conseil de recherches de la Saskatchewan, University of West Indies à la Jamaïque, Collège militaire royal à Kingston et Société radiochimique à Kanata. Tous ces réacteurs, qui sont contrôlés à distance, peuvent fonctionner sans surveillance pendant des périodes allant jusqu'à 24 heures. Sept des réacteurs

Le tableau 5 donne la liste des principaux radionucléides que l'ÉACL a fabriqués à des fins médicales et industrielles.

Tableau 5 : Production et utilisation des radionucléides

Radionucléide	Période radioactive	Type de rayonnement	Principales utilisations	Origine
Cobalt 60	5,3 années	Gamma	Stérilisation Irradiation des aliments Traitement des eaux usées Radiographie industrielle Appareils de mesure	Réacteurs de centrale et recherche
Molybdène 99	66 heures	Gamma	Matière première pour le générateur de technétium 99 (période radio-active de 6 heures); utilisé pour le scannage du cerveau, des os, des poumons et des reins	Réacteurs de recherche
Iridium 192	72 jours	Gamma	Radiographie industrielle Inspection des soudures de pipeline	Réacteurs de recherche
Xénon 133	5 jours	Gamma	Scannage des poumons	Réacteurs de recherche
Iode 131	8 jours	Gamma	Images de la thyroïde et thérapie	Réacteurs de recherche
Iode 125	60 jours	Gamma	Essais cliniques au laboratoire Radioimmunoessais	Réacteurs de recherche
Carbone 14	5 500 années	Bêta	Synthèse de composés organiques radioactifs pour la recherche biochimique, biologique et chimique	Réacteurs de recherche
Thallium 201	73 heures	Gamma	Images du coeur	Cyclotron
Gallium 67	78 heures	Gamma	Détection des tumeurs et des abcès dans les tissus mous	Cyclotron
Iode 123	13 heures	Gamma	Images de la thyroïde Médicine nucléaire expérimentale Études sur le cerveau et le coeur	Cyclotron

Source : Fiche d'information fournie par la Société radiochimique d'ÉACL.

Aujourd'hui, la Société radiochimique et la Division des produits médicaux de l'ÉACL sont sur la liste des entreprises à privatiser. La Société radiochimique sera vendue à des intérêts extérieurs, le produit de la vente revenant au gouvernement fédéral. La Division des produits médicaux de l'ÉACL sera d'abord offerte à ses propres gestionnaires et employés. En cas d'échec, elle sera aussi vendue à des intérêts extérieurs.

Le Comité applaudit l'initiative dont ces divisions ont fait preuve pour atteindre leur position actuelle. Cependant, il s'inquiète du fait que la vente de secteurs rentables de l'ÉACL puisse nuire à la position financière des autres éléments de la Corporation. Comment les recherches fondamentales et appliquées que l'ÉACL poursuit dans l'intérêt national seront-elles financées si la participation fédérale est réduite en même temps que les secteurs rentables de la société sont vendus? Le Comité est aussi préoccupé par le fait que des entreprises qui se sont développées en partie aux frais des contribuables et qui oeuvrent dans un domaine de pointe à l'échelle mondiale soient achetées par des intérêts étrangers.

Le Comité recommande au gouvernement fédéral de permettre à l'ÉACL de conserver des parts dans les sociétés privées. Si l'ÉACL conserve des parts minoritaires dans une Société radiochimique privatisée et dans une Division des produits médicaux possédée par les employés, elle peut continuer à recevoir certains avantages financiers du secteur des radionucléides qu'elle a mis plus de 35 ans à établir. Les clients sauraient alors que la société mère continue d'avoir un intérêt direct dans le succès de la Société radiochimique et de la Division des produits médicaux de l'ÉACL privatisées. La réputation internationale de l'ÉACL dans le domaine des radionucléides n'est plus à faire. En même temps, la Société radiochimique et la Division des produits médicaux de l'ÉACL pourraient s'associer en tant que sociétés privées à des entreprises conjointes, faire des acquisitions et s'accaparer rapidement de créneaux commerciaux, choses qu'elles ne peuvent faire en tant que sociétés de la Couronne. Le Comité recommande aussi qu'il soit explicitement interdit que la Société radiochimique et la Division des produits médicaux de l'ÉACL passent sous contrôle étranger, comme c'est le cas des entreprises oeuvrant dans le domaine de la mise en valeur des ressources pétrolières des régions pionnières. Le Comité ne s'oppose pas à ce que des sociétés étrangères possèdent une part minoritaire dans ces entreprises privatisées, mais il ne veut pas que le Canada perde le contrôle de ces entreprises.

Le commerce des radionucléides est une activité très internationale. C'est ainsi que l'ÉACL a travaillé dans plus de 100 pays. Avec sa base au Canada et cinq bureaux régionaux aux États-Unis, la société envisage d'étendre ses activités en installant un bureau régional en Europe, puis dans plusieurs pays en voie de développement choisis. Pour ce faire, l'ÉACL a besoin d'une plus grande souplesse en matière de décisions et de financement. Le Comité voit les avantages de la privatisation de ces opérations, mais il croit qu'il est possible de retirer les mêmes avantages si l'ÉACL conserve un rôle dans les nouvelles entreprises.

La Société radiochimique de l'ÉACL a connu bien des péripéties. Dans les années 60, une nouvelle technologie, l'accélérateur linéaire ou «linac» comme on l'appelle parfois, commença à concurrencer le cobalt 60 pour le traitement des cancers. En 1972, la société conclut qu'il fallait mettre au point des accélérateurs pour rester au premier rang dans le domaine de la radiothérapie. En utilisant les profits générés par d'autres activités, la société entreprit la mise au point d'un accélérateur linéaire perfectionné qu'elle baptisa Therac 25 (T-25). Le T-25 devait devenir la nouvelle référence en matière de linac, étant plus petit, plus puissant et moins coûteux que les autres accélérateurs sur le marché. Malheureusement, la mise au point fut beaucoup plus difficile que prévu et le T-25 se transforma en gouffre financier. Le coût du T-25 atteignit un million de dollars par appareil, ce qui signifiait un marché très limité. Pour reprendre les termes d'un observateur, «le T-25 était une merveille technologique et un cauchemar économique».

Au début des années 80, la Société radiochimique connut une crise. Il fut alors résolu de créer une nouvelle division, la Division des produits médicaux de l'ÉACL, qui se chargerait des travaux sur l'accélérateur déficitaire, de la thérapie au cobalt, des simulateurs médicaux, de la planification des traitements et de la fabrication. La Société radiochimique conserverait le secteur rentable des radioisotopes. L'ÉACL abandonnerait la mise au point de l'accélérateur. La Division des produits médicaux vit le jour en janvier 1985 et on lui donna un an pour prospérer. Grâce à un effort conjoint remarquable de l'administration de l'ÉACL, de la direction, des chefs syndicaux, des professionnels et des employés non syndiqués, la Division des produits médicaux de l'ÉACL releva le défi, mais elle dut se départir de la moitié de son personnel antérieur.

La Division des produits médicaux de l'ÉACL établit la faisabilité d'un appareil de traitement au cobalt simple et peu coûteux, mais de grande qualité, utilisable dans les pays en voie de développement et dans les hôpitaux de campagne. Un prototype, baptisé Phoenix pour symboliser la renaissance espérée, fut produit en moins de huit semaines. Un autre groupe d'employés rationalisa le secteur de la thérapie au cobalt, coupant les coûts et améliorant le service. La Division des produits médicaux de l'ÉACL commença alors à confier à des entrepreneurs les travaux qu'elle ne voulait plus effectuer à l'interne. Comme l'indique son dépliant publicitaire : «la Division des produits médicaux de l'Énergie Atomique du Canada, Limitée est fière d'offrir une gamme complète d'installations de fabrication moderne pour vos produits ou vos éléments grâce à la sous-traitance».

Le résultat fut un retournement de la situation. Après être passée de 486 employés au début de 1985 à 244 employés 14 mois plus tard, la Division des produits médicaux de l'ÉACL faisait du temps supplémentaire au début de 1986. Un an plus tard, la division avait enregistré six mois de profit consécutifs et elle réengageait certains de ses anciens employés.

l'inhibition du mûrissement des fruits et l'élimination du parasite *Trichinella spiralis* dans la viande de porc (Ontario Hydro, 1987a).

La nécessité de disposer d'appareils d'irradiation autonomes pour mener des études expérimentales sur les effets du rayonnement gamma sur divers matériaux a été établie il y a plus de 30 ans. Un prototype de cellule d'irradiation aux rayons gamma, le Gammacell 220, fut exposé à New York en 1956. Il fut à l'origine à la fois des irradiateurs de recherche et du traitement par irradiation aux rayons gamma à l'échelle industrielle. Au début de 1986, il y avait 132 irradiateurs gamma industriels en service dans 39 pays. Le plus important fournisseur d'appareils de ce type était de loin la Société radiochimique de l'ÉACL, avec 71 appareils installés dans 29 pays. Les concurrents les plus proches étaient l'Union soviétique avec 11 appareils sur son territoire, la société Marsh d'Angleterre avec neuf appareils (quatre en service au Royaume-Uni et cinq à l'étranger), le Commissariat à l'Énergie Atomique (CÉA) de France avec cinq appareils (trois en France et deux à l'étranger) et la société Radiation Sterilizers des États-Unis, avec cinq appareils aux États-Unis.

Le radiotraitement constitue une autre application de l'irradiation. Le radiotraitement consiste à utiliser un rayonnement ionisant sous forme de faisceau d'électrons ou de rayons gamma pour provoquer des modifications chimiques dans des polymères ou pour détruire des microorganismes nuisibles. Les trois principales applications du radiotraitement sont les suivantes :

1. stérilisation des produits médicaux et conservation des produits alimentaires;

2. traitement des polymères;

3. cuisson des revêtements protecteurs.

L'utilisation des rayonnements pour stériliser les produits médicaux jetables a connu un accroissement considérable depuis 1960. On choisit de préférence les rayons gamma pour les matériaux plus épais, qui requièrent une grande pénétration, et les faisceaux d'électrons lorsque le produit est relativement fin. L'irradiation des aliments pour inhiber la germination, tuer les insectes ou améliorer la conservation est une application controversée, mais prometteuse, qui a un potentiel énorme. Enfin, l'irradiation des eaux usées et des boues pour tuer les éléments pathogènes constitue un autre domaine d'application potentiellement vaste.

Les polyéthylènes, les chlorures de polyvinyle, les polyesters et les polymères fluorés sont parmi les matières plastiques qui peuvent être utilisées dans les produits irradiés. La plupart des caoutchoucs naturels et synthétiques peuvent être vulcanisés par rayonnement. Les revêtements qui peuvent être cuits électroniquement, tels les encres, les adhésifs, les matières de charge et les couches de finition, sont de plus en plus utilisés dans l'industrie.

comme sous-produit dans les installations de préparation de l'uranium d'Eldorado. Toutefois, l'approvisionnement en radium était très limité et il devint vite évident que de nouveaux produits seraient nécessaires pour combler les besoins croissants en radiothérapie. En 1947, la construction du réacteur de recherche NRX était terminée à Chalk River. Avec son flux de neutrons élevé, ce réacteur permettait de produire une variété de radionucléides ayant des niveaux d'activité supérieurs à ce que l'on pouvait trouver à ce moment-là. En particulier, la production d'un nouveau radionucléide, le cobalt 60 permit au groupe des Produits commerciaux de remplacer le radium. En 1949, le groupe des Produits commerciaux commença à commercialiser des radioisotopes produits par le réacteur NRX. Lorsque la société de l'Énergie atomique du Canada, Limitée fut créée en 1952, le groupe des Produits commerciaux fut transféré d'Eldorado à l'ÉACL.

En 1951, le groupe produisit la première bombe commerciale au cobalt 60 pour le traitement du cancer. L'ÉACL a continué la mise au point de sa gamme de bombes au cobalt 60, ajoutant récemment un système de planification de la radiothérapie complètement intégré et informatisé (commercialisé sous le nom de THERAPLAN) ainsi qu'un dosimètre tridimensionnel pour l'analyse du faisceau de rayonnement (commercialisé sous le nom de THERASCAN). À l'heure actuelle, il y a plus de 3 000 bombes au cobalt utilisées pour le traitement du cancer dans le monde. La Division des produits médicaux de l'ÉACL a conçu et construit la majorité de ces appareils, et se trouve ainsi être le plus grand fabricant mondial d'appareils pour traitement au cobalt 60. En mai 1988, la Division des produits médicaux de l'ÉACL avait installé 1 675 de ces appareils. Ces appareils ont permis de traiter environ 9,2 millions de patients et l'on estime qu'ils ont ajouté 13,8 millions d'années de vie aux 50 % de patients pour lesquels le traitement a été considéré comme un succès (la survie de ces patients a été prolongée de trois ans en moyenne).

Le Canada est le plus grand fournisseur mondial de cobalt 60, produisant environ 80 % de ce radioisotope artificiel. Le cobalt 60 est produit en irradiant du cobalt naturel (cobalt 59) dans un réacteur, et Ontario Hydro est le principal fournisseur de l'ÉACL. Le cobalt est enfermé dans des tubes en zircaloy qui sont suspendus verticalement dans les réacteurs CANDU. Le cobalt est irradié pendant environ un an, pendant le fonctionnement normal du réacteur, puis il est retiré du réacteur lors des arrêts prévus pour l'entretien. Ontario Hydro envoie alors le cobalt à la Société radiochimique de l'ÉACL.

La majeure partie du cobalt 60 est utilisée pour le traitement du cancer, mais Ontario Hydro estime que l'irradiation des aliments représente environ 5 % du marché actuel de ce radionucléide. À l'heure actuelle, il n'y a pas d'irradiation commerciale des aliments au Canada ni aux États-Unis, mais la technique est utilisée en Chine, au Japon et dans certains pays européens. Dans ce domaine, l'irradiation est utilisée à plusieurs fins, telles l'élimination des salmonelles dans la volaille et les fruits de mer,

crédit parlementaire à la Commission devrait être augmenté de façon à ce que celle-ci puisse s'acquitter de toutes ses obligations.

Le Comité est aussi de l'avis que l'ÉACL et l'industrie nucléaire n'ont pas, par le passé, accompli un travail particulièrement efficace d'éducation du public en matière d'énergie nucléaire. Les annonces et le dossier d'information produits par l'Association nucléaire canadienne sont un pas dans cette direction, mais le Comité croit qu'il reste encore beaucoup à faire pour que le public soit bien renseigné sur le programme canadien d'énergie nucléaire. Le Comité considère que la CCÉA a un rôle à jouer dans un programme d'éducation objective du public, et il recommande qu'un tel rôle soit établi à la Commission de contrôle de l'énergie atomique.

C. Le secteur des radionucléides

L'utilisation de substances radioactives en médecine remonte à la fin du XIXe siècle. Wilhelm Roentgen découvrit les rayons X en 1895 et Henri Becquerel détecta la radioactivité dans un échantillon de pechblende en 1896. Pierre et Marie Curie réussirent la séparation chimique du radium de la pechblende et, pour la première fois, on disposa d'une source concentrée de radioactivité.

La radiothérapie vit le jour à la fin des années 1890, lorsqu'on se rendit compte que le rayonnement avait des effets biologiques. On traitait des cancers superficiels au radium à la fin du siècle passé, mais on ignorait les dangers du rayonnement de sorte que les patients et le personnel médical étaient soumis à une surexposition pendant les séances de diagnostic et de thérapie.

Les chercheurs apprirent rapidement qu'il y avait au moins trois types différents de rayonnement émis par les éléments radioactifs. Ces rayonnements furent baptisés alpha, bêta et gamma (les trois premières lettres de l'alphabet grec). Le rayonnement alpha est le moins pénétrant et le rayonnement bêta est un peu plus pénétrant. Le rayonnement gamma, quant à lui, est hautement pénétrant et requiert une protection maximale.

On se rendit compte que la radiothérapie nécessitait des doses de rayonnement soigneusement contrôlées et, avec la mise au point du tube à rayons X dans les années 1920, il devint possible de concevoir des appareils ayant le degré de souplesse et de réglage approprié. La mise au point au cours de la Seconde Guerre mondiale des techniques micro-ondes et des générateurs de radiofréquences très puissants mena à la conception réussie d'accélérateurs linéaires micro-ondes et à leur utilisation en médecine et dans l'industrie.

Au Canada, un groupe des Produits commerciaux fut formé en 1946 au sein de la société Eldorado Mining and Refining Ltd. dans le but de vendre le radium obtenu

atomique. De concert avec l'ÉACL, la CCÉA administre le Programme canadien à l'appui des garanties visant à aider l'AIÉA à améliorer les méthodes et les techniques de surveillance. Les travaux récents réalisés en vertu de ce programme ont porté surtout sur l'accroissement de la fiabilité de certains dispositifs de surveillance installés sur quatre réacteurs CANDU 600 et sur la mise au point finale de certains autres dispositifs de surveillance pour ces réacteurs (Canada, CCÉA, 1988).

Le Comité s'inquiète toutefois de remarques provenant de différentes sources selon lesquelles la Commission de contrôle de l'énergie atomique n'a pas les ressources financières et humaines suffisantes pour remplir toutes ses obligations. La CCÉA qui paraissait devant le présent Comité au sujet de son Budget principal des dépenses 1988-1989 a indiqué qu'elle avait besoin d'un budget accru de 50 % pour être en mesure de s'acquitter de toutes ses responsabilités actuelles. [Il faudrait environ cinq ans pour que la CCÉA puisse absorber un tel accroissement de financement et de dotation en personnel.] La CCÉA est en retard dans ses engagements en matière de garanties nucléaires envers l'AIÉA parce qu'elle n'a pas les ressources suffisantes pour mettre en place les programmes et installer le matériel de surveillance pour lequel le Canada a donné son accord (un problème aggravé par les récentes coupures financières à l'ÉACL, qui administre ce programme de concert avec la CCÉA). La CCÉA n'a pu effectuer la R et D indépendante qu'elle considérait nécessaire relativement aux problèmes métallurgiques éprouvés dans les tubes de force de certains réacteurs CANDU.

Le Comité a aussi appris que le manque de personnel à la Commission entraînait des retards en matière de délivrance de permis et dans d'autres domaines. L'ÉACL a demandé que la CCÉA étudie la délivrance générique de permis pour le réacteur CANDU 300, un aspect important de la commercialisation pour l'ÉACL. Cependant, la CCÉA a beaucoup de travail à effectuer en vue de la mise en marche de l'installation de Darlington, et l'étude d'un «réacteur sur papier» n'a pas la même priorité, de sorte qu'elle n'a pas encore commencé d'étude de la délivrance générique pour le CANDU 300. Un autre exemple est la demande de construction d'un réacteur SLOWPOKE que l'Université de Sherbrooke présentera à la CCÉA. Cette activité subira aussi des retards étant donné que les travaux de la Commission sur les demandes de réacteurs de puissance ont la priorité.

Le Comité conclut que cette insuffisance des ressources à la CCÉA est intolérable, compte tenu de l'importance de son rôle de réglementation. Selon le Comité, il y a deux mesures à prendre pour corriger la situation. D'abord, la loi de mise en vigueur pour la CCÉA devrait être modifiée afin de permettre à la Commission de récupérer un partie des coûts liés à ses activités de délivrance de permis. [Le Comité préférerait voir la CCÉA récupérer la plus grande part possible de ses coûts par le biais de mécanismes de recouvrement, mais il ne croit pas qu'on ait intérêt à affirmer arbitrairement que la Commission doit réaliser une récupération complète des coûts.] Si une récupération partielle des coûts ne fournit pas de fonds additionnels suffisants, le

nucléaire dont ils peuvent être responsables en raison de négligence ou de méfaits volontaires; et que la Loi élimine le poids d'une plus grande responsabilité, lequel inciterait les fournisseurs et les exploitants à prendre des mesures visant à réduire les risques d'accidents nucléaires. En septembre 1987, un juge de la Cour suprême de l'Ontario décida que le recours en justice était prématuré et basé sur un argument hypothétique, et qu'Enquête énergétique n'avait pas le statut requis pour maintenir le recours. Enquête énergétique a ensuite porté la cause devant la Cour d'appel de la Cour suprême de l'Ontario, où la question reste à résoudre (Ontario Hydro, 1987a).

Le Comité éprouve aussi certaines craintes au sujet de l'assurance-responsabilité nucléaire au Canada, et il a conclu que l'assurance courante est insuffisante. Compte tenu des réclamations découlant de l'accident de Three Mile Island (pour lequel le Comité a été informé que les réclamations dépassent maintenant un milliard de dollars US) et de l'accident de Chernobyl (pour lequel les rapports laissent entrevoir des dommages atteignant les trois milliards de dollars), une protection maximale au Canada de 75 millions de dollars n'est pas compatible avec l'expérience acquise dans le règlement de situations de ce genre. En Allemagne de l'Ouest, où il n'y a jamais eu d'accident grave dans le programme nucléaire, la limite de responsabilité de l'exploitant (services publics) est environ dix fois plus élevée qu'au Canada. Aux États-Unis, une responsabilité totale partagée par les exploitants de tous les réacteurs de puissance américains en vertu de la *Price-Anderson Act* sera portée à environ 7 milliards de dollars US, une fois que le Congrès aura reconduit la loi qui a expiré en août 1987. Chaque exploitant de réacteurs aura une responsabilité d'un montant allant jusqu'à 63 millions de dollars US par réacteur, qui devra être versé par paiements annuels de 10 millions de dollars US dans un fonds d'indemnisation à la suite d'un accident causant des dommages publics. Cette responsabilité civile est contractée auprès d'assureurs privés jusqu'à concurrence de 160 millions de dollars US.

Le Comité n'est pas prêt à faire des recommandations quant au niveau accru de responsabilité civile canadienne à imposer aux exploitants d'installations nucléaires désignées; il ne fait que constater que les limites actuelles sont insuffisantes. Le Comité a été informé qu'un groupe de travail interministériel avait terminé un examen de la *Loi sur la responsabilité nucléaire*, notamment de la pertinence des montants d'assurance fixés, et qu'il présentera bientôt ses résultats au président de la CCÉA. Le Comité espère que cet examen se traduira par une meilleure protection financière, dans le cas peu probable où se produirait un accident grave dans une installation canadienne.

Parmi ses autres attributions, la Commission de contrôle de l'énergie atomique voit à ce que le Canada respecte les protocoles internationaux en matière de garanties nucléaires. Le Canada a signé le *Traité de non-prolifération des armes nucléaires* (habituellement appelé le Traité de non-prolifération ou T.N.P.) et est de ce fait une partie d'un accord de garanties conclu avec l'Agence internationale de l'énergie

La NIAC n'offre pas toute la garantie requise en vertu de la Loi pour les installations nucléaires; c'est pourquoi le gouvernement fédéral maintient un Compte de réassurance de responsabilité nucléaire, qui fait partie du Fonds du revevu consolidé. Le 31 mars 1988, la garantie supplémentaire offerte par le gouvernement du Canada en vertu de la *Loi sur la responsabilité nucléaire* était de 641,6 millions de dollars. Cette réassurance étend la couverture sur chaque installation nucléaire à 75 millions de dollars, conformément aux exigences de la Loi (ainsi, un réacteur de recherche SLOWPOKE ou une usine de fabrication de combustibles est couvert jusqu'à la limite de 75 millions de dollars par la réassurance fédérale). La réassurance fédérale couvre aussi les risques qu'a exclus la NIAC en tant qu'assureur principal. La NIAC ne couvre pas les dommages résultant des émissions d'exploitation normale dans les installations nucléaires, ni la différence entre le préjudice corporel et le préjudice personnel (ce qui signifie que les réclamations pour préjudice mental ou psychologique sont exclues de la protection offerte par la NIAC). Le gouvernement du Canada assume ces risques par le biais de sa garantie supplémentaire (Communication personnelle : Bob Blackburn, CCÉA, 11 juillet 1988). Jusqu'à maintenant, aucune réclamation n'a été adressée au Compte de réassurance de responsabilité nucléaire.

Advenant un accident nucléaire à la suite duquel on peut s'attendre à ce que les réclamations dépassent les limites de responsabilité civile fixées, la *Loi sur la responsabilité nucléaire* prévoit l'établissement d'une Commission des répartitions des dommages nucléaires pour régler toutes les réclamations découlant de l'accident. Lorsque les paiements dépassent le montant de l'assurance responsabilité, le Parlement doit autoriser tout paiement additionnel. En vertu de la loi canadienne, toutes les réclamations sont adressées à l'exploitant de l'installation. Ni le public ni un exploitant ne peuvent poursuivre un fournisseur pour dommages résultant d'un accident nucléaire (bien qu'un exploitant puisse poursuivre un fournisseur pour d'autres considérations). Le requérant doit prouver que les dommages ou le préjudice ont été causés par l'accident nucléaire à l'installation de l'exploitant. Cette question n'est pas toujours simple, étant donné que les cancers provoqués par les rayonnements peuvent n'apparaître que 20 ou 30 ans après l'exposition (la loi fixe une limite de 10 ans pour les demandes d'indemnisation), et il peut être difficile, voire impossible, d'établir une relation de cause à effet.

En avril 1987, Enquête énergétique a contesté devant la Cour suprême de l'Ontario la *Loi sur la responsabilité nucléaire* en soutenant que la Loi viole certaines des dispositions de la *Charte canadienne des droits et libertés*. En particulier, Enquête énergétique soutient que le temps prévu par la Loi pour qu'une personne puisse intenter une action est trop court; que la Loi limite le montant total d'indemnisation dont peuvent bénéficier les personnes qui ont été victimes de préjudice personnel ou dont les biens ont été endommagés que la Loi protège les fournisseurs et les concepteurs de matériel et de produits nucléaires de toute responsabilité liée à un accident

Centrales Pickering A et B	1 064 000 $
Centrales Bruce A et B	603 000 $
Centrale NPD (récupérée de l'ÉACL)	33 000 $

Tableau 4 : Polices d'assurance responsabilité de base sur les installations nucléaires canadiennes, au 31 mars 1988

Installation	Montant de l'assurance de base
Centrale Bruce A (4 réacteurs)	75 000 000 $
Centrale Bruce B (4 réacteurs)	75 000 000 $
Centrale Gentilly 2 (1 réacteur)	75 000 000 $
Centrale NPD (1 réacteur)	23 400 000 $
Centrales Pickering A et B (8 réacteurs)	75 000 000 $
Centrale Point Lepreau (1 réacteur)	75 000 000 $
Réacteur SLOWPOKE, University of Alberta	500 000 $
Réacteur SLOWPOKE, Dalhousie University	500 000 $
Réacteur de recherche, McMaster University	1 500 000 $
Réacteur SLOWPOKE, École polytechnique	500 000 $
Réacteur SLOWPOKE, Saskatchewan Research Council	500 000 $
Réacteur SLOWPOKE, University of Toronto	500 000 $
Raffinerie de Port Hope, Les Ressources Eldorado Limitée	4 000 000 $
Usine de fabrication de combustibles de Port Hope, Zircatec Precision Industries Inc.	2 000 000 $

Note : Dans le cas des réacteurs de puissance, on considère qu'une installation nucléaire comprend tous les réacteurs qui partagent un système de confinement. Ainsi, la centrale Lepreau 1 constitue une installation, tout comme les huit réacteurs de Pickering qui sont tous reliés à un système de confinement commun. Le complexe Bruce est composé de deux installations aux fins de la Loi, puisqu'il y a un système de confinement par groupe de quatre réacteurs.

Source : Canada, CCÉA, *Rapport annuel 1987-1988*, Ottawa, 1988, p. 24.

Tableau 3 : Permis pour radioisotopes en vigueur au Canada le 31 mars 1988, par type d'utilisateur

Types d'utilisateur	Nombres de permis
Hôpitaux et autres établissements médicaux	732
Universités et autres établissements d'enseignement	328
Organismes gouvernementaux	557
Secteur privé	
Forage pétrolier	101
Radiographie	190
Calibrage	1 428
Éliminateurs de statique	775
Fournisseurs	209
Autres	538
Total	**4 858**

Source : Canada, CCÉA, *Rapport annuel 1987-1988*, Ottawa, 1988, p. 6.

Le coût des primes d'assurance annuelles que doit payer l'exploitant dépend de facteurs comme la densité de population et la valeur des terrains à proximité de chaque installation. Il ne s'est produit aucun accident de réacteur de puissance au Canada qui ait eu des effets nuisibles sur le public et, par conséquent, aucune réclamation n'a été présentée à l'une des trois entreprises de services publics qui exploitent des réacteurs de puissance. Le tableau 4 montre les montants d'assurance de base fixés pour chaque installation nucléaire désignée au Canada.

En 1986, l'Ontario Hydro a payé 1,733 million de dollars en primes afin d'obtenir l'assurance responsabilité requise pour ses réacteurs de puissance. En 1987, le coût des primes s'élevait à 1,7 million de dollars, dû à la récupération du réacteur de Douglas Point par l'ÉACL en octobre 1986. Les primes pour 1987 étaient réparties comme suit (Ontario Hydro, 1987a, p. 96) :

B. Régime de réglementation et responsabilité nucléaire

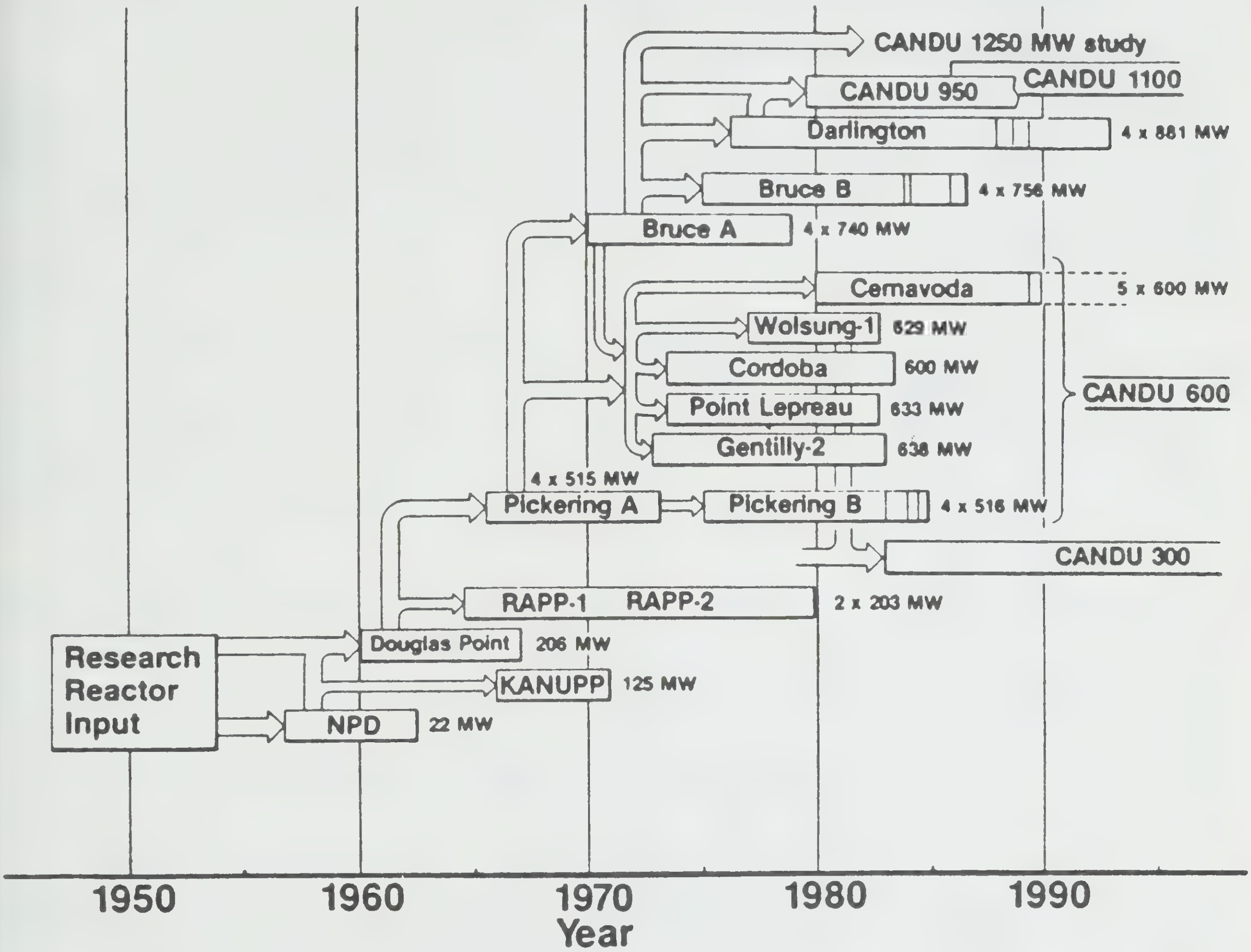
La délivrance de permis à l'industrie nucléaire canadienne relève de la Commission de contrôle de l'énergie atomique (CCÉA), créée en 1946 par la *Loi sur le contrôle de l'énergie atomique* et dont l'administration centrale est à Ottawa. La CCÉA délivre des permis pour les réacteurs de puissance, les réacteurs de recherche, les accélérateurs de particules, les mines et les usines de concentration d'uranium, les raffineries d'uranium et les usines de fabrication de combustibles, les usines d'eau lourde et les installations de gestion de déchets radioactifs. Deux comités consultatifs secondent la CCÉA; il s'agit du Comité consultatif de la radioprotection et du Comité consultatif de la sûreté nucléaire.

La CCÉA délivre deux types de permis : 1) des permis pour substances prescrites, dont 47 étaient en vigueur au 31 mars 1988; et 2) des permis pour radioisotopes, dont 4 858 étaient en vigueur. Les substances prescrites sont notamment l'uranium, le thorium et l'eau lourde. La répartition des permis pour radioisotopes par type d'utilisateur est donnée au tableau 3. C'est en Ontario qu'on trouve le plus grand nombre (2 136) de détenteurs de ce type de permis, puis au Québec (1 060), en Alberta (589) et en Colombie-Britannique (452).

Au cours de l'exercice 1987-1988, la CCÉA a effectué 2 800 contrôles auprès des utilisateurs de radioisotopes afin de vérifier s'ils se conformaient aux Règlements de la Loi sur le contrôle de l'énergie atomique ainsi qu'aux conditions des permis. De nombreux titulaires de permis sont donc contrôlés moins d'une fois l'an. Il est à souligner que l'utilisation de certains dispositifs, comme les détecteurs de fumée, ne nécessite pas de permis parce que la quantité de radioactivité est très petite et parce que le dispositif est conçu pour la contenir en toute sécurité.

La CCÉA est aussi chargée d'appliquer la *Loi sur la responsabilité nucléaire* de 1970. La Commission désigne les installations nucléaires et, avec l'approbation du Conseil du Trésor, fixe le montant d'assurance responsabilité civile de base que doit souscrire l'exploitant pour chaque installation. Cette couverture s'applique aux réclamations du public advenant un accident nucléaire; elle ne peut pas servir à défrayer les coûts de réparation des installations endommagées de l'exploitant. Le Pool canadien d'assurance des risques atomiques (NIAC), un consortium de compagnies d'assurance autorisées à oeuvrer au Canada, est la seule source commerciale approuvée de laquelle l'exploitant d'une installation commerciale désignée peut obtenir une assurance responsabilité.

Graphique 7 : Étapes du développement de la filière CANDU



Source : Meneley, Daniel A., "Ontario Hydro's CANDU Nuclear Stations: An Outline of Safety-related Design Aspects" dans Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review. Vol. 2 Appendices*, Appendix I, Toronto, 29 février 1988, p. I/2.

Une récente étude de gestion, effectuée par CRESOP, une firme d'experts-conseil de New York, met temporairement dans l'ombre cette situation en révélant que 10 % des employés de l'Ontario Hydro sont surnuméraires et qu'ils devraient être recyclés et affectés à d'autres postes. La compagnie a déclaré un gel de l'embauche en attendant le résultat des études en cours sur l'amélioration de la productivité.

Le graphique 7 résume les étapes du développement du réacteur CANDU, du prototype de réacteur de démonstration NPD jusqu'à l'étude d'un réacteur CANDU de 1 250 MW.

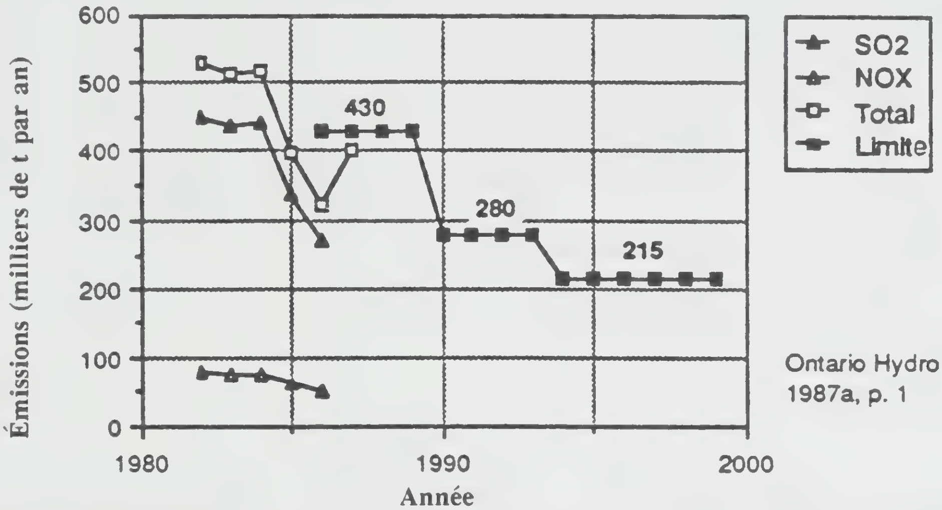
Un certain nombre de réacteurs CANDU ont été construits à l'étranger. La série de modèles a commencé par la construction du réacteur Kanupp de 125 MWe (puissance nette) près de Karachi (Pakistan). Ce réacteur a été mis en service en 1971. Deux réacteurs de 203 MWe (puissance nette), Rapp-1 et Rapp-2, ont ensuite été construits près de Delhi en Inde. Rapp-1 a été mis en service en 1972; Rapp-2, pas avant 1980. Ce retard reflète l'arrêt de la coopération entre le Canada et l'Inde dans le domaine nucléaire après que celle-ci eût fait sauter une installation nucléaire en mai 1974. Bien qu'elle ait été privée de l'aide canadienne en matière d'énergie nucléaire, l'Inde a continué de construire le réacteur de type CANDU-PHWR par ses propres moyens. Depuis que le Canada a mis fin à son aide, l'Inde a aussi terminé la construction des réacteurs Mapp 1 et 2 et Narora 1 et 2, qui ont tous une puissance similaire aux réacteurs Rapp (et au réacteur de Douglas Point, duquel ils dérivent).

L'ÉACL a connu du succès dans la vente d'une série de réacteurs CANDU 600 à l'étranger. Deux de ces réacteurs sont déjà en exploitation : le réacteur Cordoba de 600 MWe à Embalse en Argentine et le réacteur Wolsung de 629 MWe en Corée du Sud. Cinq réacteurs CANDU 600 sont en construction en Roumanie, les réacteurs Cernavoda 1-5. On est en retard dans le calendrier du programme roumain en raison des exigences relatives au contenu roumain. L'industrie de la Roumanie n'a pas été en mesure de fabriquer des composants nucléaires présentant une haute qualité uniforme et le taux de rejet a été excessif.

Un problème de main-d'oeuvre, peu remarqué, est en train de se créer dans le programme nucléaire canadien. Il y a un manque grandissant de personnel professionnel et technique dans le domaine nucléaire; l'Ontario Hydro, l'ÉACL et l'industrie ont de plus en plus de difficultés à trouver le personnel dont ils ont besoin. Les employés bien formés ressentent une perte d'intérêt pour le programme nucléaire et voient leurs possibilités d'avancement réduites à mesure que le programme énergétique est comprimé; certains quittent déjà le domaine et vont travailler ailleurs. À cela s'ajoute l'attrition normale de la main-d'oeuvre attribuable aux retraites et aux changements de carrières. Les universités et les écoles techniques canadiennes ne produisent pas une relève de professionnels et de techniciens suffisante pour maintenir le programme nucléaire dans sa forme actuelle. Une fois de plus, le Canada doit envisager la possibilité de faire venir de l'étranger la main-d'oeuvre spécialisée requise, comme il l'a fait dans les premières années de mise en oeuvre du nucléaire au pays.

L'Ontario Hydro et les émissions de gaz acides

L'Ontario Hydro estime que ses centrales alimentées au charbon produisent environ 20 % des émissions totales de gaz acides de l'Ontario, dioxyde de souffre (S02) et oxydes d'azote (NO2), ou 1 % des émissions totales de l'Amérique du Nord. Le graphique montre les émissions annuelles de l'Ontario Hydro pour la période 1982-1986 et les limites d'émission qui sont présentement appliquées par la province de l'Ontario à l'entreprise (430 000 tonnes d'émissions totales de gaz acides pour la période 1986-1989; 280 000 tonnes pour la période 1990-1993; et 215 000 tonnes à compter de 1994).



Afin de réduire les émissions, l'Ontario Hydro a : accru la production à partir de l'énergie nucléaire; réduit la teneur en soufre du charbon brûlé; acheté de l'hydro-électricité du Québec et du Manitoba; et effectué des essais sur des brûleurs à faible production de NOx. Chaque réacteur de la centrale Pickering permet d'éviter l'émission d'environ 50 000 tonnes/année de gaz acides, et chaque réacteur de la centrale Bruce, environ 75 000 tonnes/année. Chaque nouveau réacteur de la centrale Darlington permettra d'éviter l'émission d'environ 90 000 tonnes/année. Sans les centrales Pickering et Bruce, le volume des émissions de gaz acides de l'Ontario Hydro serait trois fois plus importants. En mélangeant du charbon à faible teneur en soufre de l'Ouest canadien avec du charbon américain à plus forte teneur en soufre, l'Ontario Hydro évite l'émission d'environ 90 000 tonnes de gaz par année, mais cette opération lui coûte un supplément de 60 millions de dollars par année. Le lavage de la plus grande partie du charbon qu'elle achète des États-Unis lui permet d'en réduire la teneur en soufre d'environ 20 %. Les tuyères de brûleurs à faible production de NOx qui ont été mises à l'essai à la centrale Nanticoke alimentée au charbon semblent permettre une réduction des émissions d'oxydes d'azote d'environ 35 % (Ontario Hydro, 1987a, p. 2-3).

Toutefois, ces stratégies ne permettront pas de respecter la limite plus sévère prévue pour 1994, étant donné que la demande d'électricité augmente. L'Ontario Hydro annonçait en février 1988 qu'elle demandait l'approbation du gouvernement pour installer des épurateurs (appareils de désulfuration des gaz de combustion) dans ses trois plus grosses centrales alimentées au charbon. Ensemble, la centrale Lakeview de 2 286 MW, la centrale Nanticoke de 4 336 MW et la centrale Lambton de 2 100 MW comptent pour plus de 90 % de l'électricité produite par l'Hydro dans ses centrales alimentées au charbon. Quatre techniques différentes de désulfuration des gaz de combustion ont été évaluées et les avantages de chacune ont été décrits dans une étude environnementale présentée par l'Ontario Hydro au ministre de l'Environnement, l'honorable James Bradley. Les épurateurs seraient installés par paires afin de desservir chaque groupe électrogène et leur coût approximatif serait de 220 millions de dollars (1987) la paire. L'Ontario Hydro pourrait devoir moderniser jusqu'à huit groupes électrogènes alimentés au charbon de 500 MW dans les trois centrales entre 1994 et l'an 2000. Le coût annuel d'utilisation de chaque paire d'épurateurs s'élèvera jusqu'à 12 millions de dollars, et une équipe permanente de 50 à 120 personnes sera requise à chaque centrale pour assurer le fonctionnement et l'entretien des épurateurs (Ontario Hydro, 1988b).

centrales CANDU en exploitation (Brooks et Hart, 1988; Canada, ÉACL, *Exploitation CANDU*, non daté).

L'ÉACL répond à une tendance mondiale confirmée dans une étude réalisée en 1985 par l'Agence internationale de l'énergie atomique (AIÉA). L'AIÉA a déterminé que les accroissements de la puissance dans les pays non communistes, au cours de la période de 5 ans s'étendant de 1985 à 1989, seraient en général attribuables à des centrales au charbon d'une puissance de 400 MW environ. C'est le marché qu'on vise avec le CANDU 300, dont la puissance nominale nette est de 450 MWe. Du point de vue de la puissance, l'étude de l'AIÉA indique que 39,3 % de la puissance additionnelle serait produite par des centrales nucléaires; 38,6 %, par des centrales au charbon; 6,4 %, par des centrales au mazout; et 6,3 %, par des centrales hydro-électriques (Brooks et Hart, 1988).

Afin de réduire le coût d'immobilisation du CANDU 300, l'ÉACL a élaboré un calendrier de construction de 35 mois (de la première coulée de béton à l'exploitation pleine puissance) pour le premier réacteur et un calendrier de seulement 30 mois pour les réacteurs subséquents. On croit atteindre ce résultat grâce à une conception modulaire qui limite le poids de chaque module à environ 300 tonnes (en deça de la capacité d'une grue très puissante) et en ayant recours à des techniques de construction très perfectionnées.

L'ÉACL a essayé de vendre un CANDU 300 à la CÉÉNB afin de démontrer la viabilité du modèle. Bien que les négociations se poursuivent, l'ÉACL n'a pu jusqu'à maintenant obtenir un engagement de la CÉÉNB pour la construction d'un CANDU 300. La Commission d'énergie électrique du Nouveau-Brunswick a éprouvé de graves difficultés financières lors de la construction de la centrale Lepreau 1, dont la mise en service a été retardée et pour laquelle le dépassement des coûts a été élevé, et elle a déclaré publiquement qu'elle n'envisagerait l'acquisition d'un CANDU 300 que si le gouvernement fédéral assumait le coût d'immobilisation et les frais financiers additionnels qu'entraînerait l'addition d'un tel réacteur à son système au lieu de l'addition d'un groupe alimenté au charbon de 400 mégawatts. D'après l'entreprise, le coût d'immobilisation additionnel, y compris les frais financiers pour la période d'amortissement, s'élève à environ 1 milliard de dollars.

Le Comité aimerait qu'une entente soit conclue, mais sans qu'il en coûte un milliard de dollars au Trésor public. Si une entente satisfaisante pour les deux parties peut être conclue, en vertu de laquelle l'ÉACL détiendrait peut-être des intérêts minoritaires dans un deuxième réacteur à Point Lepreau, comme elle le fait pour Pickering 1 et 2, la commande d'un CANDU 300 par la CÉÉNB constituerait une étape importante dans la commercialisation de ce type de réacteur à l'étranger.

En Ontario, en 1987, l'électricité produite à partir de l'énergie nucléaire a permis de répondre à 47,5 % de la demande; l'électricité produite à partir de combustibles fossiles, à 23,9 % de la demande ; et l'électricité produite à partir de l'énergie hydraulique, à 23,8 % de la demande. L'an dernier, en raison de l'utilisation de combustibles fossiles (principalement du charbon) pour la production d'électricité, l'Ontario Hydro a rejeté dans l'atmosphère presque 400 000 tonnes de gaz acides : dioxyde de soufre et oxydes d'azote. Bien qu'elles aient été considérablement inférieures à la valeur de crête atteinte en 1982 (531 000 tonnes), les émissions totales de gaz acides de l'Ontario Hydro en 1987 étaient beaucoup plus élevées qu'en 1986, en raison du temps sec et des bas niveaux d'eau, qui ont entraîné une baisse de la production à partir de l'énergie hydraulique d'environ 15 % et une hausse de la consommation de charbon de moitié environ supérieure à la consommation prévue de 1987. En vertu de nouveaux règlements provinciaux plus sévères annoncés en 1985, la société doit réduire ses émissions de gaz acides au-dessous de 215 000 tonnes en 1994 (Ontario Hydro, 1988).

L'électronucléaire a grandement contribué à réduire les émissions de gaz acides en Ontario. L'énergie nucléaire permet à l'Ontario Hydro de réduire de plus de la moitié ses émissions de gaz acides dans l'atmosphère et à l'Ontario de réduire de plus de 10 % ses émissions totales de gaz acides.

Après de nombreuses années de perfectionnement à l'échelle mondiale, au cours desquelles la taille des réacteurs a augmenté plus ou moins continuellement, ÉACL a reconnu qu'il fallait aussi un réacteur de plus petite taille. Les petits réacteurs ont un coût total moins élevé (bien que le coût par mégawatt de puissance installée soit plus élevé), ce qui réduit le fardeau et le risque financiers. Ces réacteurs peuvent être intégrés plus facilement aux systèmes des petites entreprises de services publics. Le produit de cette approche adoptée par ÉACL en matière d'évolution des réacteurs est le CANDU 300, dont la conception sera bientôt terminée. Les petites compagnies d'électricité, particulièrement dans les pays en voie de développement, font le marché visé par le CANDU 300.

Le modèle CANDU 300 d'ÉACL est plus simple que les premiers CANDU. Par exemple, l'utilisation de bus de données et de multiplexeurs dans les systèmes de commande du CANDU 300 réduit le câblage d'instrumentation de 80 % par comparaison à celui du CANDU 600. Alors que le CANDU 600 (qui aura une puissance nominale nette de 750 MW dans les nouvelles centrales) comprend quatre générateurs de vapeur et quatre pompes primaires de caloportage, le CANDU 300 (puissance nominale nette de 450 MW) comprend deux générateurs de vapeur et deux pompes principales de caloportage. Le CANDU 300 comprendra une machine de réapprovisionnement alors que le CANDU 600 en comprenait deux. Les composants clés, tels générateurs de vapeur, pompes de caloportage, tubes de force et machines de chargement, seront identiques à ceux qui ont déjà fait leurs preuves en service dans les

Tableau 2 : Historique des réacteurs de puissance au Canada

Réacteur	Endroit	Type	Puissance (MWe net)	Exploitant	Exploitation commerciale	État
NPD	Rolphton (Ont.)	PHWR	22	Ont. Hydro	1962	Arrêt 1987
Douglas Point	Tiverton (Ont.)	PHWR	206	Ont. Hydro	1968	Arrêt 1984
Pickering 1	Pickering (Ont.)	PHWR	515	Ont. Hydro	1971	Exploitation
Pickering 2	Pickering (Ont.)	PHWR	515	Ont. Hydro	1971	Exploitation
Pickering 3	Pickering (Ont.)	PHWR	515	Ont. Hydro	1972	Exploitation
Pickering 4	Pickering (Ont.)	PHWR	515	Ont. Hydro	1973	Exploitation
Gentilly 1	Gentilly (Qué.)	BLW	250	Hydro-Qué.	1972	Arrêt 1978
Gentilly 2	Gentilly (Qué.)	PHWR	638	Hydro-Qué.	1983	Exploitation
Bruce 1 (a)	Tiverton (Ont.)	PHWR	740	Ont. Hydro	1977	Exploitation
Bruce 2 (a)	Tiverton (Ont.)	PHWR	740	Ont. Hydro	1977	Exploitation
Bruce 3 (a)	Tiverton (Ont.)	PHWR	740	Ont. Hydro	1978	Exploitation
Bruce 4 (a)	Tiverton (Ont.)	PHWR	740	Ont. Hydro	1979	Exploitation
Pt. Lepreau	P. Lepreau (N.-B.)	PHWR	633	NBEPC	1983	Exploitation
Pickering 5	Pickering (Ont.)	PHWR	516	Ont. Hydro	1983	Exploitation
Pickering 6	Pickering (Ont.)	PHWR	516	Ont. Hydro	1984	Exploitation
Pickering 7	Pickering (Ont.)	PHWR	516	Ont. Hydro	1985	Exploitation
Pickering 8	Pickering (Ont.)	PHWR	516	Ont. Hydro	1985	Exploitation
Bruce 6 (b)	Tiverton (Ont.)	PHWR	756	Ont. Hydro	1984	Exploitation
Bruce 5 (b)	Tiverton (Ont.)	PHWR	756	Ont. Hydro	1985	Exploitation
Bruce 7 (b)	Tiverton (Ont.)	PHWR	756	Ont. Hydro	1986	Exploitation
Bruce 8 (b)	Tiverton (Ont.)	PHWR	756	Ont. Hydro	1987	Exploitation
Darlington 2	Darlington (Ont.)	PHWR	881	Ont. Hydro	1989	Construction
Darlington 1	Darlington (Ont.)	PHWR	881	Ont. Hydro	1989	Construction
Darlington 3	Darlington (Ont.)	PHWR	881	Ont. Hydro	1991	Construction
Darlington 4	Darlington (Ont.)	PHWR	881	Ont. Hydro	1992	Construction

(a) Les réacteurs de Bruce A ont été reclassés à 769 MWe (si on compte la vapeur industrielle fournie à la centrale à eau lourde Bruce, leur puissance nette est de 848 MW).

(b) Les réacteurs de Bruce B sont présentement reclassés à 875 MWe.

Source : Canada, ÉACL, *Coup d'oeil sur le nucléaire*, Affaires publiques du bureau central, Ottawa, septembre 1987, p. G-4 et G-5; Ontario, Nuclear Safety Review, *The Safety of Ontario's Nuclear Reactors: A Scientific and Technical Review. A Submission to the Ontario Nuclear Safety Review by Atomic Energy of Canada Limited*, Toronto, 29 février 1988, fig. 2-2.

la série CANDU 600 soit, dans le cas de l'Hydro-Québec, une unité d'une puissance nette de 638 MWe située à Gentilly et, dans celui de la CÉÉNB, un réacteur d'une puissance nette de 633 MWe situé à Point Lepreau sur la côte de l'Atlantique. Le dossier de fonctionnement de ces deux unités est exceptionnellement bon.

Lorsque la CÉÉNB compléta la centrale Lepreau 1, la puissance de celle-ci représentait une augmentation d'environ 25 % de l'électricité produite au Nouveau-Brunswick. Normalement, une centrale électrique n'augmente pas la puissance produite de beaucoup plus que d'environ 10 % de la puissance existante du système, à cause des problèmes posés par le remplacement de cette puissance lorsque l'unité est hors service. Étant donné les liens interactifs importants entre le Nouveau-Brunswick et le Québec, la Nouvelle-Écosse et la Nouvelle-Angleterre, il a été possible de passer outre à cette règle; toutefois, cela s'est fait non sans une augmentation des risques pour la stabilité du réseau du Nouveau-Brunswick.

Trois provinces canadiennes ont donc fait des investissements pour la production d'électricité nucléaire. L'Ontario exploitera bientôt 20 réacteurs pour produire de l'électricité : les huit unités de la centrale Pickering, les huit unités de la centrale Bruce et les quatre unités de la centrale Darlington. Le réacteur de Douglas Point et celui de NPD, situés en Ontario, sont fermés et en train d'être mis hors service. Au Québec, deux unités ont été construites à Gentilly : le réacteur expérimental refroidi à l'eau bouillante de la centrale Gentilly 1, dont la mise hors service est en cours, et le réacteur CANDU 600 de la centrale Gentilly 2. Au Nouveau-Brunswick, il existe une unité CANDU 600 à Point Lepreau. Depuis 1962, 21 réacteurs produisant de l'électricité ont été mis en service au Canada; trois de ces réacteurs sont en train d'être mis hors service et quatre autres sont en voie de construction. On ne prévoit présentement aucun autre développement. Le tableau 2 est un résumé de la mise en oeuvre des réacteurs de puissance au Canada.

Les 18 réacteurs exploités en Ontario, au Québec et au Nouveau-Brunswick ont une puissance nette de 11 971 MWe (en tenant compte de la réévaluation, à 875 MWe, de la puissance nominale des unités de la centrale Bruce B — qui était en cours au moment de la rédaction du présent texte — mais sans inclure de crédits pour la vapeur produite par les unités de la centrale Bruce A). Les quatre unités en construction à Darlington ajouteront 3 524 MWe à la puissance nette des centrales nucléaires du Canada qui sera donc en 1992 de 15 495 MWe au total.

Les centrales à unités multiples de l'Ontario ont les puissances suivantes : 1) Centrale nucléaire (CN) Pickering A = 2 060 MWe; 2) CN Pickering B = 2 064 MWe; 3) CN Bruce A = 3 076 MWe; 4) CN Bruce B = 3 500 MWe (après réévaluation de sa puissance nominale); et 5) CN Darlington A = 3 524 MWe.

nucléaires de Whiteshell au Manitoba. Ce type de réacteur a été nommé CANDU-OCR pour indiquer qu'il s'agit d'une combinaison d'un modérateur à l'eau lourde et d'un système de refroidissement organique dont le réfrigérant est une huile légère spécialement conçue. Le liquide organique s'est montré un milieu caloporteur plus efficace, ce qui permet une température plus élevée du réfrigérant pendant le fonctionnement du réacteur, le rendant plus efficace thermodynamiquement que le réacteur CANDU standard. En comparaison de l'eau lourde, le réfrigérant organique a aussi l'avantage d'abaisser le niveau de rayonnement émis pendant le fonctionnement du réacteur. Ce réacteur expérimental, qui fonctionnait au carbure d'uranium enrichi, a atteint sa pleine puissance en 1965 et a fonctionné jusqu'en 1985. Bien que le réacteur refroidi par une substance organique ait semblé offrir des promesses de développement et que des études poussées aient été effectuées par l'ÉACL jusqu'en 1970, le succès de la centrale Pickering A a continué de centraliser les intérêts sur le réacteur CANDU-PHWR.

L'Ontario Hydro a commencé la construction de la première de ses centrales à unités multiples, la centrale Pickering A sur le lac Ontario à l'est de Toronto. De 1971 à 1973 quatre réacteurs d'une puissance nette de 515 MWe ont été mis commercialement en service à Pickering A. Quatre unités d'une puissance nette de 740 MWe ont ensuite été mises en service à la centrale Bruce A sur le lac Huron (1977-79). Quatre unités d'une puissance nette de 516 MWe sont ensuite venues s'ajouter à la centrale Pickering B (1983-85) et quatre réacteurs d'une puissance nette de 756 MWe, à la centrale Bruce B (1984-87). Les centrales nucléaires de Pickering et de Bruce se classent parmi les plus gros complexes nucléaires producteurs d'électricité au monde. Quatre réacteurs d'une puissance nette de 881 MWe sont présentement en construction au nouveau site de Darlington sur le lac Ontario. Ces unités entreront en service de 1989 à 1992. En 1987, la moitié de l'électricité utilisée en Ontario provenait d'unités nucléaires; en 1992, lorsque la centrale de Darlington sera terminée, cette proportion passera environ au deux tiers.

On a estimé la puissance nominales des grosses unités CANDU avec beaucoup de prudence. La puissance des unités de la centrale Bruce A a déjà été augmentée de 740 MWe à 769 MWe (soit une puissance nette de 848 MW, si l'on tient compte de la vapeur que ces unités fournissent à l'usine d'eau lourde Bruce). La puissance nette des unités de Bruce B a été réévaluée à 875 MWe (Ontario Hydro, 1986b, p. 5).

Le réacteur que l'ÉACL a conçu par la suite est le CANDU 600. Cette unité combine les meilleurs éléments des réacteurs utilisés à Pickering et à Bruce ainsi qu'un certain nombre d'améliorations technologiques. Le réacteur CANDU 600 est conçu comme une unité individuelle confinée de façon classique dans un immeuble, contrairement aux centrales à quatre unités de l'Ontario Hydro qui ont un système de confinement sous vide commun. L'Hydro-Québec et la Commission d'énergie électrique du Nouveau-Brunswick (CÉÉNB) ont toutes deux décidé de construire un réacteur de

réacteurs, puisqu'il a servi de modèle pour les centrales RAPP-1 et RAPP-2 d'une puissance nette de 203 MWe mises en service à Rajasthan, en Inde, en 1963.

En raison de la pénurie d'eau lourde au Canada, le réacteur de Douglas Point a été retiré du service d'avril à décembre 1972, son stock de D_2O ayant servi à mettre en service le réacteur de Pickering. Le réacteur de Douglas Point a été exploité jusqu'en mai 1984, date à laquelle son propriétaire, l'ÉACL, a offert de le vendre à son exploitant, l'Ontario Hydro. Cette dernière a cependant décidé que son exploitation n'était plus rentable, en raison de sa petite taille, de la nécessité de remplacer ses tubes de force et de l'insuffisance des lignes de transmission partant du site de Bruce. L'ÉACL a alors fermé définitivement le réacteur en janvier 1985. Le réacteur de Douglas Point est ainsi devenu le premier réacteur CANDU-PHWR à être mis «en veilleuse»; il faudra attendre 30 ans avant de démonter le réacteur et d'éliminer ses éléments. Le stock complet de combustible irradié a été placé dans des conteneurs de béton qui sont provisoirement stockés sur place, sans mouillage. Ce programme de stockage est décrit dans la section intitulée «La gestion des déchets radioactifs au Canada» (ÉACL, CANDU Operations, *The Douglas Point Story*, 1984; Broad, 1986).

Une variante du réacteur modéré à l'eau lourde, connue sous le nom de CANDU-BLW, a été construite par l'ÉACL pour l'Hydro-Québec à Gentilly sur les bords du Saint-Laurent. Ce prototype de réacteur électrique de dimensions commerciales ayant une puissance nette de 250 MWe — connu sous le nom de Gentilly 1 — était modéré à l'eau lourde et refroidi par ébullition d'eau ordinaire. Il s'agissait d'une conception de remplacement pour le CANDU-PHWR dans l'éventualité où les pertes d'eau lourde utilisée comme réfrigérant aux centrales Douglas Point et Pickering A se seraient montrées trop coûteuses. La conception du réacteur de Gentilly 1 était à tubes de force à l'intérieur d'un coeur vertical. Le fait de laisser bouillir l'eau ordinaire servant de réfrigérant à l'intérieur des tubes de force, ce qui réduit ses capacités d'absorption massique et neutronique, permet de continuer à faire fonctionner le réacteur à l'uranium naturel. Le système de commande du réacteur s'est cependant avéré fort complexe et des problèmes de conception et de mise en service sont survenus. Depuis sa mise en service en 1972 jusqu'à la fin de son exploitation commerciale en 1977, la centrale Gentilly 1 a fonctionné à pleine puissance pour seulement quelques semaines au total. Le réacteur a servi à des fins de formation jusqu'en 1979, moment où la décision fut prise de reléguer la centrale aux oubliettes. En 1983, l'ÉACL décida de mettre la centrale Gentilly 1 hors service. Le combustible épuisé fut transféré dans des conteneurs de béton et stocké à sec temporairement dans l'immeuble abritant les turbines. Heureusement pour le procédé PHWR, les pertes d'eau lourde survenues à Douglas Point et à Pickering se sont avérées passablement faibles et l'intérêt pour un réacteur de type CANDU-BLW est disparu (Thexton, 1987; Denault et De, 1985).

Une autre conception a été appliquée dans la construction du réacteur expérimental WR-1 d'une puissance de 40 MWt à l'Établissement de recherches

par le dessus, au moyen d'un château de transfert de 240 tonnes, qui en permettait l'alimentation pendant le fonctionnement. En mai 1958, une barre de combustible s'est brisée pendant la décharge du réacteur et la contamination résultante a entraîné la fermeture de ce dernier pendant six mois. Contrairement au NRX qui avait été surtout conçu par les scientifiques britanniques travaillant à Chalk River, le NRU était un réacteur à eau lourde de conception canadienne. Le NRX et le NRU ont attiré les chercheurs de plusieurs pays. Un aspect fortuit de cette collaboration a été que le Canada a pu se servir très tôt d'un nouvel alliage de zirconium, le zircaloy, mis au point par la société Westinghouse pour le Programme américain des sous-marins nucléaires. Les alliages de zirconium devaient rendre possible la construction d'un réacteur à tubes de force (Thexton, 1987; Bothwell, 1988).

L'étape suivante a été la construction d'un prototype de réacteur de puissance. L'ÉACL, l'Ontario Hydro et la société Générale Électrique du Canada ont mis leurs ressources en commun pour concevoir et construire le NPD de 22 MWe (puissance nette)[1] à Rolphton, en Ontario, près de Chalk River. Ce réacteur de puissance de démonstration appartenait à l'ÉACL, mais était exploité par l'Ontario Hydro. Le réacteur est entré en service en 1962 et a été exploité jusqu'en 1987. On est en train de le mettre hors service. Le NPD a été conçu comme un réacteur à cuve sous pression et à coeur vertical, malgré l'inquiétude des ingénieurs canadiens qui ne savaient pas s'il allait être possible de construire une cuve sous pression suffisamment grande pour contenir le coeur d'un réacteur à eau lourde de taille commerciale. La cuve en question avait déjà été commandée de la Babcock & Wilcox, en Écosse, quand l'alliage zircaloy devint disponible et qu'il fut possible de concevoir un réacteur à tubes de force. Les travaux de conception de la cuve sous pression ont donc été arrêtés et le NPD a été transformé en réacteur à tubes de force. Le NPD a aussi servi de modèle pour la construction de la centrale KANUPP de 125 MWe (puissance nette) située près de Karachi, au Pakistan (Thexton, 1987; Bothwell, 1988; Ontario, Nuclear Safety Review, 1988a).

L'Ontario Hydro et l'ÉACL ont ensuite collaboré à augmenter la puissance de la filière NPD, en construisant le réacteur de démonstration de Douglas Point d'une puissance nette de 206 MWe, sur la rive est du lac Huron, au nord de Kincardine. Ce site devint par la suite l'emplacement de la centrale Bruce à huit tranches. La décision de construire le réacteur de démonstration a été prise en 1959; la mise en service de ce réacteur était prévue pour 1964. Le réacteur de Douglas Point n'a en fait été mis en service qu'en 1967, mais l'Ontario Hydro avait suffisamment confiance en sa conception qu'elle a tout de suite commencé l'étude de la centrale Pickering A, à unités multiples, avant même sa mise en service. Ce réacteur a également aidé le Canada à exporter ses

---

1. La puissance nette = puissance brute - le service de la centrale. La puissance nette représente l'électricité disponible après avoir tenu compte de la demande et des pertes d'électricité de la centrale.

LE DÉVELOPPEMENT DU NUCLÉAIRE AU CANADA

A. Le programme des réacteurs de puissance

L'eau lourde, D_2O, a été découverte en 1930. On s'est aperçu rapidement qu'elle pouvait servir de modérateur (substance qui ralentit les neutrons). L'eau lourde a été un bien stratégique au cours de la Deuxième Guerre mondiale; les Alliés tout comme le Troisième Reich s'acharnaient alors à produire les premiers la bombe atomique. La France avait acheté les stocks mondiaux d'eau lourde la veille de la déclaration de la guerre, et une partie de ces stocks ont été transférés d'abord en Angleterre, puis au Canada, où les équipes de recherche canadiennes et britanniques ont travaillé à construire le premier réacteur à eau lourde. Pendant ce temps, les Alliés sabotaient les installations des Allemands, empêchant ceux-ci d'obtenir suffisamment d'eau lourde de la seule usine de production du monde située en Norvège pour pouvoir poursuivre leur effort de recherche.

Le premier réacteur nucléaire du Canada a été un réacteur expérimental de puissance nulle, le ZEEP. Ce réacteur, construit à Chalk River, dans l'est de l'Ontario, fut le premier à fonctionner hors des États-Unis, son démarrage ayant eu lieu en septembre 1945. Le but de son exploitation était de confirmer les paramètres de conception d'un plus gros réacteur et d'exécuter des essais en vue de la construction d'un réacteur à eau lourde. (Thexton, 1987)

Le ZEEP a été suivi d'un réacteur expérimental de recherche de 20 mégawatts thermiques (MWt), le NRX, dont l'exploitation a commencé à Chalk River en 1947. Ce réacteur de recherche à eau lourde devait servir à produire du plutonium, mais il s'est avéré un excellent banc d'essai pour divers combustibles et substances nucléaires, en raison de ses grandes dimensions et de son flux neutronique élevé. En décembre 1952, le NRX était gravement endommagé par un accident causé par l'erreur humaine et par la défectuosité mécanique des barres d'arrêt. Le NRX ne possèdait pas de système d'arrêt rapide et aucun système de confinement. Avant que la réaction en chaîne ait pu être stoppée par vidange du modérateur, les éléments structuraux et les éléments combustibles avaient subi d'importants dommages et des substances radioactives s'étaient échappées. Il a fallu 14 mois pour remettre en état le réacteur qui a été remis en service avec une puissance doublée à 40 MWt. L'accident du NRX, le premier et le plus sérieux à se produire au Canada, a eu une influence majeure sur l'ingénierie de la sûreté des réacteurs de puissance qui lui ont succédé (Thexton, 1987; Ontario, Nuclear Safety Review, 1988d, p. 42).

C'est en 1957 que le réacteur NRU de 200 MWt, réacteur universel de recherche, a commencé à fonctionner à Chalk River. Le coeur vertical du réacteur était chargé

Tableau 1 : Différences entre le CANDU–PHWR et le PWR

CANDU–PHWR	PWR
• Combustible à uranium naturel (0,7 % d'U 235)	• Combustible à uranium enrichi (1 à 3 % d'U 235)
• Refroidi et ralenti au D_2O	• Refroidi et ralenti au H_2O
• Réapprovisionnement en marche – facteur de charge supérieur – taux de combustion du combustible supérieur – extraction du combustible défectueux en marche	• Réapprovisionnement par lots pendant un arrêt
• Tubes de force	• Cuve sous pression
• Taille du coeur supérieure et puissance volumique inférieure	• Taille du coeur inférieure et puissance volumique supérieure
• Coût d'immobilisation relativement élevé	• Coût d'immobilisation relativement faible
• Tuyauterie plus complexe	• Tuyauterie moins complexe
• Bâtiment sous vide aux stations à plusieurs unités	• Différentes méthodes de suppression de la pression
• Confinement à débit de fuite supérieur	• Confinement à débit de fuite inférieur
• Coefficient de vide positif	• Coefficient de vide négatif
• Production et émission relativement élevées de tritium et de carbone 14	• Production et émission faibles de tritium et de carbone 14
• Confinement partagé aux stations de l'Ontario Hydro	• Systèmes de confinement indépendants
• Adaptation facile au cycle du combustible au thorium	• Sans objet

deuxième étapes de la fabrication de l'eau lourde se déroulent dans des tours d'échange dont le haut est froid (32°C) et le bas est chaud (128°C). Le sulfure d'hydrogène gazeux se déplace vers le haut dans ces tours, et l'eau vers le bas. Le mélange des deux est facilité par une série de plateaux perforés. On obtient ainsi un enrichissement en deutérium au centre des tours.

Le sulfure d'hydrogène gazeux enrichi en deutérium est extrait de la section centrale de la première tour et amené à la deuxième tour où se poursuit son enrichissement. La teneur en deutérium du sulfure d'hydrogène gazeux passe de 0,015 % à 0,07 % dans la première tour, puis à 0,35 % environ dans la deuxième. Une troisième étape d'enrichissement permet d'obtenir un produit renfermant entre 10 % et 30 % d'eau lourde. La dernière étape, une distillation, donne de l'eau lourde de «qualité réacteur» contenant 99,75 % d'oxyde de deutérium. Le procédé de production de l'eau lourde consomme de très grandes quantités d'eau : environ 340 000 tonnes pour chaque tonne d'eau lourde produite. (Ontario Hydro, *Heavy Water*, non daté). Le coût d'exploitation d'une usine d'eau lourde ne dépend presque pas du taux de production : on ne fait presque aucune économie en ne fonctionnant pas à plein rendement. Le coût unitaire de production d'eau lourde augmente donc sensiblement lorsque la production diminue. Pour plus d'information sur le coût de production de l'eau lourde par Ontario Hydro et sur les sommes investies par le gouvernement fédéral dans la fabrication d'eau lourde, voir le chapitre intitulé «Les aspects économiques de l'énergie nucléaire».

La sécurité est un souci constant dans une usine d'eau lourde. Le sulfure d'hydrogène est en effet un gaz toxique, incolore, légèrement plus lourd que l'air. Il faut donc protéger le personnel de l'usine et les collectivités voisines de toute concentration dangereuse de ce gaz.

L'ÉACL a démantelé ses usines d'eau lourde de Glace Bay et de Port Hawkesbury en Nouvelle-Écosse. Des quatre usines d'eau lourde de 800 tonnes/an planifiées par l'Ontario Hydro à l'emplacement de la centrale Bruce, seule l'usine B est en exploitation. Chacun des réacteurs de la centrale Darlington nécessitera une charge initiale d'eau lourde équivalant à la production annuelle environ de cette usine. Les usines A et D sont en veilleuse, tandis que l'usine C n'a jamais été construite. L'usine de 800 tonnes/an de LaPrade, à Gentilly, est également en veilleuse. L'ÉACL a donc sur les bras un stock coûteux d'eau lourde invendue, qu'elle cherche à vendre en faisant concurrence à l'Ontario Hydro.

Le tableau 1 résume les principales différences entre le réacteur à eau lourde sous pression (CANDU-PHWR) et le réacteur à eau ordinaire sous pression (PWR).

l'ouverture des robinets. L'enceinte sous vide étant gardée à environ un dixième de la pression atmosphérique, la vapeur radioactive sera automatiquement aspirée dans celle-ci. L'enceinte sous vide est dotée d'un système d'arrosage qui condensera la vapeur, réduisant ainsi au minimum les risques de fuite de radioactivité du système de confinement dans l'environnement. Le dernier obstacle est la zone d'exclusion d'un kilomètre entourant le site de la centrale, qui permet une certaine dilution de la radioactivité avant que celle-ci n'atteigne une zone résidentielle.

4) La formation des opérateurs est un autre important facteur de la sûreté. Ainsi que le montrent les accidents survenus par le passé, l'erreur humaine est presque invariablement un élément substantiel et parfois dominant de tout accident grave. Le personnel de l'Ontario Hydro est formé pendant au moins huit années et doit subir une série d'examens établis par la compagnie et par la CCÉA avant d'obtenir son permis d'opérateur.

5) Le dernier facteur est la détection et la correction des pannes. Un programme continu d'essai et d'inspection, couplé à des systèmes automatiques de détection des pannes, sert à garantir que le réacteur fonctionne bien et que toute panne détectée est immédiatement corrigée.

Ce ne sont pas tous les accidents de réacteurs qui sont prévus ou dont on évalue correctement la probabilité avant qu'ils ne se produisent. Ainsi, on pensait que la rupture d'un tube de force d'un réacteur CANDU serait annoncée d'abord par une fuite, la prétendue hypothèse de la «fuite avant la rupture». En l'occurrence, la rupture d'un tube de force survenue à la centrale Pickering 2 a été soudaine, le tube se brisant sans aucun signe annonciateur. Néanmoins, les opérateurs ont bien réagi et arrêté le réacteur à l'aide du système d'arrêt normal (sans avoir à recourir au système de secours) dans ce cas, qui constituait le plus grave accident survenu à l'époque dans un réacteur CANDU. La rupture d'un tube de force survenue à Pickering 2, en dépit de ses conséquences économiques, a fait la preuve de la sûreté de la filière CANDU en dépit d'une perte majeure de caloporteur.

Le réacteur CANDU nécessite de grandes quantités d'eau lourde (oxyde de deutérium, D^2O) qui sert à la fois de modérateur et de caloporteur. Le Canada a considérablement investi dans des installations de production d'eau lourde en mettant en oeuvre un programme qui, au départ, ne suffisait pas à répondre à la demande et qui, par la suite, a entraîné la production d'une trop grande quantité d'eau lourde, étant donné que les ventes de réacteurs ne se matérialisaient pas.

Le procédé de production de l'eau lourde est fondé sur le comportement du deutérium dans un mélange d'eau liquide et de sulfure d'hydrogène gazeux. Dans un tel mélange, les atomes de deutérium se déplacent librement entre le liquide et le gaz : vers le gaz à haute température et vers le liquide à basse température. Les première et

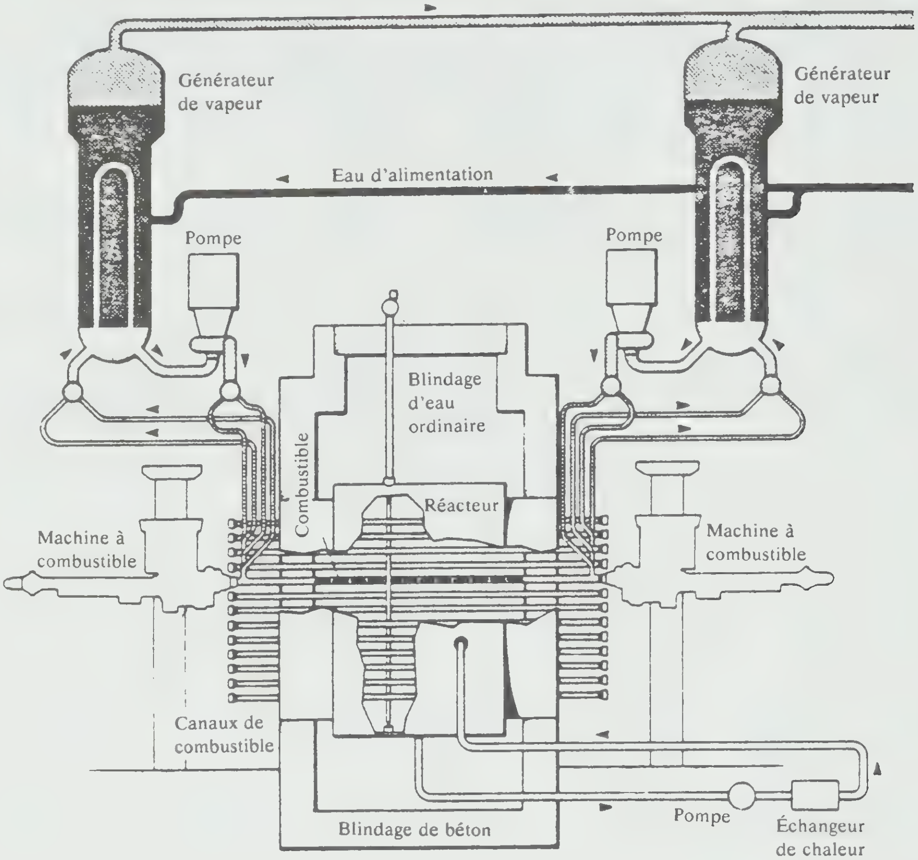
électromagnétiques : toute panne de l'alimentation a donc pour effet de faire plonger les barres dans le réacteur, et de l'arrêter.

Les réacteurs CANDU possèdent deux classes générales de circuit de sûreté : des **circuits d'arrêt du réacteur** et un **système de refroidissement de secours du coeur** (SRSC). Chacun des réacteurs CANDU possède deux circuits d'arrêt indépendants, appartenant à l'un des trois types de circuits d'arrêt conçus pour ces réacteurs. Tous les réacteurs CANDU sont équipés de **barres d'arrêt** composées de cadmium absorbant les neutrons. L'introduction rapide des barres d'arrêt met fin à la réaction en chaîne, car il ne reste plus suffisamment de neutrons pour l'entretenir. Certains réacteurs CANDU sont munis d'une **vidange du modérateur**, système qui permet d'évacuer rapidement le modérateur dans un réservoir de retenue placé sous le réacteur. La vidange du modérateur garantit que les neutrons rapides ne seront pas ralentis pour créer d'autres fissions, et que la réaction en chaîne s'arrête donc. Dans d'autres réacteurs CANDU, on trouve un système **d'injection d'un poison**, c'est-à-dire qu'un liquide présentant de bonnes propriétés d'absorption des neutrons peut être injecté sous pression dans le modérateur. Le liquide injecté absorbe un grand nombre de neutrons et «empoisonne» ainsi la réaction en chaîne.

Le SRSC est mis en marche dès que le refroidissement du réacteur ne fonctionne pas, comme ce pourrait être le cas si un bris majeur se produisait dans le circuit de refroidissement primaire. De l'eau stockée dans un réservoir est alors injectée sous pression par le circuit de refroidissement de secours, inonde le combustible et transporte la chaleur de fission hors du coeur.

3) Le troisième facteur consiste à créer une série de barrières physiques qui contiennent la radioactivité ou qui réduisent au minimum son émission dans l'atmosphère, que ce soit pendant l'exploitation normale du réacteur ou pendant une situation d'urgence. La première barrière est constituée par le combustible même qui, à moins de bris imprévu des pastilles de combustible, retient 99 % de la radioactivité créée pendant le fonctionnement normal du réacteur. Le combustible CANDU est fabriqué sous la forme de pastilles de céramique de dioxyde d'uranium (UO_2) dont le point de fusion est de 2800°C. Les pastilles de combustible sont contenues dans des tubes de zircaloy scellés, ce qui constitue un autre obstacle à la dispersion de la radioactivité. Les faisceaux de combustible sont placés dans des tubes de force à l'intérieur du circuit fermé de refroidissement primaire. Le réacteur et ses principales structures sont placés dans un immeuble à paroi de béton épaisse et, dans le cas des centrales à plusieurs réacteurs de l'Ontario Hydro, raccordés à une enceinte sous vide par un conduit de grande dimension muni de robinets à ouverture sous pression. S'il se produit une rupture importante dans le circuit de refroidissement primaire, le caloporteur s'en échappant formera rapidement de la vapeur dont la pression provoquera

Graphique 6 : Principaux éléments du réacteur CANDU



Source : Thexton, H.E., "Canada" dans *Nuclear Power: Policy and Prospects*, P.M.S. Jones (éd.), John Wiley & Sons, Toronto, 1987, p. 203.

qu'une seule est nécessaire. Par indépendance, on entend que les circuits ou les éléments fonctionnent indépendamment les uns des autres. On prévoit ainsi des circuits d'alimentation indépendants pour les circuits distincts. Enfin, par **sûreté intégrée**, on entend que la panne d'un élément ou d'un circuit fait automatiquement passer en état de sûreté cet élément ou ce circuit. Ainsi, des barres d'arrêt peuvent être tenues au-dessus du réacteur au moyen de pinces

(Ontario Hydro, 1987a, p. 121-122). Ainsi, les pertes économiques liées à l'arrêt de deux réacteurs pendant plusieurs années pour fins de remplacement des tubes ont été importantes[1]. Néanmoins, le rendement des réacteurs CANDU, dont la plupart sont exploités par l'Ontario Hydro, reste impressionnant lorsqu'il est comparé à celui des autres modèles.

> Les rendements élevés obtenus par l'Ontario Hydro sont particulièrement remarquables. Cette société jouit encore de la durée de vie [facteur de charge] la plus élevée bien que pendant quatre ans deux de ses quinze réacteurs aient été arrêtés pour un remplacement complet des tubes de force suite à une défaillance de tube survenue en 1983 et qu'ils ne soient remis en service qu'aujourd'hui (Howles, 1988, p. 22).

Le graphique 6 illustre les principaux éléments du réacteur CANDU, le circuit caloporteur primaire et les générateurs de vapeur.

Le Canada a été un chef de file de l'élaboration d'une méthode systématique de réduction au minimum des risques de l'exploitation des réacteurs. La notion de la prévention et de l'atténuation des accidents par une conception supérieure, l'utilisation de matériels de haute qualité et le recours à du personnel bien formé est appelée «défense en profondeur». Ce souci de sécurité est l'un des héritages de l'accident du réacteur NRX survenu en 1952 à Chalk River. Dans la défense en profondeur, on fait l'hypothèse que la conception du réacteur présente des imperfections, que le matériel tombera parfois en panne et que les opérateurs du réacteur commettront des erreurs à l'occasion. Son but est de réduire au minimum la probabilité qu'il se produise un accident, et s'il s'en produit un, d'en réduire au minimum les conséquences.

Ainsi que l'expose l'Ontario Hydro, la notion de défense en profondeur repose sur cinq facteurs (Ontario Hydro, 1987a, p. 101-104).

1) La première ligne de défense est constituée par l'utilisation de matériels de haute qualité fabriqués d'après des normes strictes.

2) Dans le cas d'une panne survenant dans un circuit majeur du réacteur, des circuits indépendants de sûreté sont actionnés pour compenser ou corriger la panne. Ces circuits de sûreté sont conçus, chaque fois qu'il est possible de le faire, en tenant compte de certains principes d'exploitation. Par **isolement**, on entend que toute panne survenant à un endroit ou dans un circuit donné n'affectera pas les éléments à d'autres endroits ou dans d'autres circuits. Par **diversité**, on entend qu'il existe plus d'un moyen pour parvenir à un résultat, comme arrêter le réacteur. Par **redondance**, on entend qu'il existe plus d'un élément pouvant effectuer une tâche donnée; on raccorde ainsi **deux pompes en parallèle, alors**

---

1. Les coûts de retubage et de l'énergie de remplacement sont partagés à peu près également par les trois propriétaires des unités Pickering 1 et 2, soit l'Ontario Hydro, la province de l'Ontario et l'ÉACL. L'entente de récupération des investissements nucléaires s'appliquant à ces réacteurs est analysée dans la section intitulée «Les aspects économiques de l'énergie nucléaire».

remplaçables, de sorte que les autres types de réacteurs ont une durée de vie plus limitée.

L'utilisation de tubes de force donne au CANDU un avantage important du point de vue de l'exploitation : la possibilité de réapprovisionnement en marche. Alors que les autres types de réacteurs doivent être arrêtés pour le réapprovisionnement, le CANDU peut continuer de fonctionner à pleine puissance pendant que des machines de réapprovisionnement commandées à distance introduisent les grappes de combustible dans le coeur ou les extraient. Des éléments combustibles défectueux peuvent aussi être retirés pendant que le réacteur est en marche. Une grande partie des qualités de fonctionnement supérieures du CANDU peuvent être rattachées à la possibilité de réapprovisionnement en marche. Comme les tubes de force sont horizontaux, les nouvelles grappes de combustible peuvent simplement être introduites par une extrémité des tubes par une machine de chargement et les grappes de combustible épuisé peuvent être retirées à l'autre extrémité par une autre machine de chargement. Avec cette configuration, il est aussi possible d'insérer les grappes de combustible neuf à partir d'extrémités opposées de canaux de combustible adjacents et d'obtenir ainsi une distribution plus uniforme de puissance sur toute la longueur du réacteur. Un autre avantage lié à cette approche est la possibilité de fabriquer des grappes de combustible courtes de modèle simple.

L'adoption d'un réacteur à tubes de force ne s'est pas faite sans présenter des inconvénients. La tuyauterie beaucoup plus complexe du coeur d'un réacteur CANDU est un facteur qui contribue au coût d'immobilisation plus élevé pour la construction de ce type de réacteur, ce qui constitue un aspect important à une époque où les frais financiers sont élevés et où les échéances prévues aux calendriers de construction sont souvent reportées. De plus, les premiers espoirs voulant que le réacteur à tubes de force ait une durée de vie de 30 ans ont été anéantis. Le remplacement prématuré des tubes, d'abord de Pickering 1 et 2, à la suite de la rupture de tube de l'unité 2 en 1983, et bientôt de Pickering 3 et 4[1], en dépit de l'utilisation dans les tubes d'un alliage zirconium-niobium plus perfectionné, a constitué une déception coûteuse. Le coût direct des matériaux, de la main-d'oeuvre et de l'équipement nécessaires pour enlever et reposer les tubes de force et de remise en service des unités 1 et 2 a été estimé récemment à 402 millions de dollars par l'Ontario Hydro. L'énergie de remplacement pour la perte de production nucléaire d'électricité a coûté chaque jour de 200 000 $ à 250 000 $ environ par unité, selon le type d'énergie de remplacement (électricité produite par des centrales au charbon d'Ontario Hydro ou achetée à d'autres services publics)

---

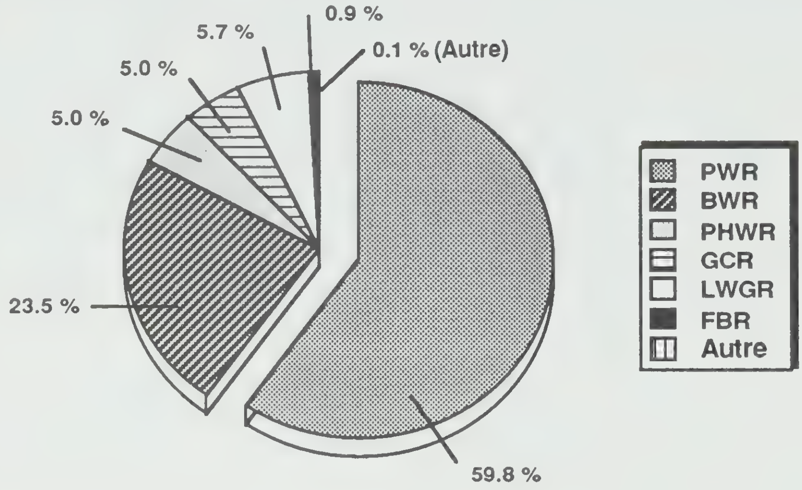
1. Ontario Hydro a annoncé que l'unité 3 de Pickering sera fermée en 1989, et l'unité 4, en 1991, pour fin de remplacement des tubes. Le remplacement des tubes de ces unités a été prévu pour la fin des années 1990. Le service public prévoit que les travaux dureront 23 mois à l'unité 3 et 19 mois à l'unité 4, et coûteront 500 millions de dollars au total. La décision a été prise après qu'Ontario Hydro a découvert qu'il y avait absorption plus forte que prévue de deutérium dans les tubes de force des unités 3 et 4 (Ontario Hydro, 1988c).

qui existe dans la nature) et à utiliser dans le coeur des matières qui réduisent l'absorption des neutrons. Le terme CANDU, un acronyme pour CANada-Deutérium-Uranium, désigne un type de réacteur de puissance distinct lancé au Canada, qui est basé sur cette dernière approche. Le CANDU élimine ainsi les coûts additionnels liés à la mise en oeuvre d'installations d'enrichissement de l'uranium (ou à la dépendance par rapport à un fournisseur étranger pour l'approvisionnement en combustible enrichi) et atténue l'intérêt économique que présente le retraitement du combustible épuisé, ce qui a pour effet d'éliminer encore une étape coûteuse dans le cycle du combustible nucléaire.

Le CANDU est ralenti et refroidi à l'eau lourde, de façon à tirer profit de la section efficace de capture des neutrons exceptionnellement basse de l'isotope deutérium. Toutefois, l'eau lourde est un produit coûteux, et elle contribue à accroître de façon appréciable le coût d'immobilisation du réacteur CANDU. Il y a aussi un coût lié à l'eau lourde d'appoint étant donné que de petites quantités sont perdues en conditions normales de fonctionnement. Le taux de perte a été inférieur à 1 % du stock d'eau lourde par année. Les craintes initiales à l'effet que les pertes d'eau lourde puissent entraîner des pertes financières importantes ont ainsi été effacées. Le stock d'eau lourde dans les anciens CANDU est d'environ 1 tonne par mégawatt de puissance; dans les nouveaux réacteurs, qui sont plus puissants, il est d'environ 0,8 tonne par mégawatt. Les alliages de zirconium, qui absorbent beaucoup moins de neutrons que l'acier, sont utilisés pour fabriquer les éléments de structure et les gaines des éléments combustibles, ce qui ajoute à l'économie de neutrons que le modèle CANDU permet de réaliser.

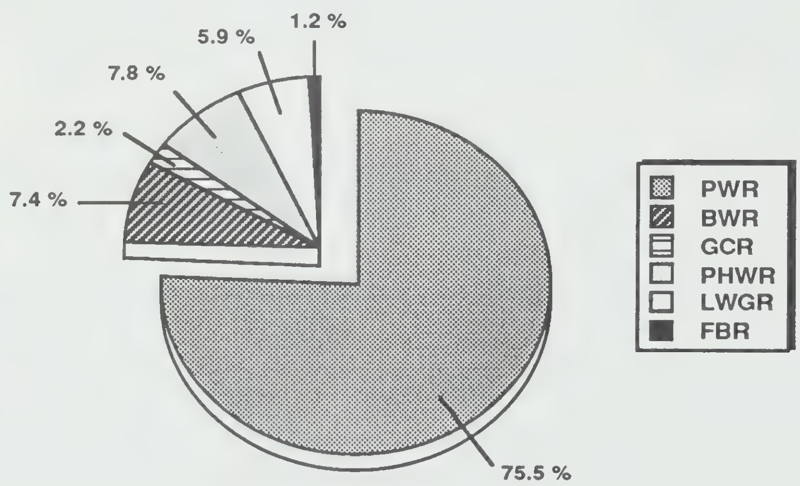
Étant donné la plus faible puissance volumique dans un coeur de réacteur CANDU, condition qui est liée à l'utilisation de combustible à uranium naturel, le coeur est beaucoup plus gros que celui des autres types de réacteurs de puissance nominale comparable. Les premiers concepteurs du CANDU craignaient qu'il soit très difficile de fabriquer une cuve sous pression destinée aux réacteurs CANDU de grande puissance, vu sa grosseur, et ils ont plutôt opté pour un système à tubes de force pour confiner les grappes de combustible à l'intérieur du coeur. Les grappes de combustible sont par conséquent confinées à l'intérieur d'un grand nombre de tubes de force indépendants qui transportent aussi l'eau lourde chaude sous pression utilisée comme caloporteur. Grâce à ce type de conception, le caloporteur et le modérateur peuvent être maintenus dans des circuits distincts et le modérateur froid à basse pression peut être confiné à l'intérieur d'une cuve relativement simple appelée la calandre. Par contre, le caloporteur et le modérateur ne font qu'un dans le LWR, et ils doivent être confinés à l'intérieur d'une grosse cuve sous pression complexe à parois épaisses. Les tubes de force sont remplaçables, et l'Ontario Hydro est en train de devenir un expert en la réalisation de cette tâche. Il est possible que les réacteurs CANDU soient en mesure de fonctionner pendant de nombreuses décennies, moyennant le remplacement périodique des tubes de force et d'autres éléments. Les cuves sous pression ne sont pas

Graphique 4 : Réacteurs exploitables dans le monde au 31 juillet 1987



Source : Nuclear Engineering International, "Reactor Statistics", *World Nuclear Industry Handbook 1988*, Reed Business Publishing, Sutton, Angleterre, 1988, p. 10.

Graphique 5 : Réacteurs en construction dans le monde au 31 juillet 1987



Source : Nuclear Engineering International, "Reactor Statistics", *World Nuclear Industry Handbook 1988*, Reed Business Publishing, Sutton, Angleterre, 1988, p. 10.

durée d'exploitation, et le BWR, 61,4 %. Le GCR représente 5 % de la capacité des réacteurs exploitables et seulement 2,2 % de la capacité des réacteurs en construction.

Le réacteur à eau lourde, dans la version PHWR dont le Canada est le pionnier, représente 5 % de la capacité des réacteurs exploitables et 7,8 % de la capacité des réacteurs en construction. Le PHWR a une fiche d'exploitation supérieure, affichant, au milieu de 1987, un facteur de charge de 75,5 % par rapport à sa capacité. Malgré sa performance supérieure, le PHWR n'a pas réussi à pénétrer autant le marché mondial des réacteurs que le modèle à eau légère. En termes de capacité prévue, le PHWR représente à peine 2 % des 141 GW de capacité des 149 réacteurs prévus. En fait, lorsque l'étude a été effectuée, il était prévu qu'un seul nouveau réacteur CANDU serait installé par une société d'électricité canadienne (et cela reste à confirmer) et que seulement 6 réacteurs PHWR seraient installés dans d'autres pays (cinq en Inde, sans aucun contrat pour le Canada, et un en Turquie).

Les modèles LWGR représentent 5,7 % de la capacité de production exploitable et 5,9 % de la capacité en construction. La part occupée par les LWGR dans le marché des réacteurs en construction est constituée entièrement par six gros RBMK qui sont présentement en construction en URSS.

Les surrégénérateurs rapides ne représentent que 0,9 % de la capacité de production exploitable et 1,2 % de la capacité en construction. Ils représenteront toutefois une part croissante de la capacité de production dans le futur, à mesure que le marché de l'énergie de fission se développera.

Les graphiques 4 et 5 résument les parts du marché détenues au milieu de 1987 par les principaux types de modèles de réacteurs exploitables et de réacteurs en construction, respectivement. Il est évident que le modèle PWR domine le marché.

C. La filière CANDU

Il existe deux approches fondamentales pour la conception d'un réacteur en vue de maintenir une réaction en chaîne. L'une consiste à augmenter la concentration en atomes fissibles dans les éléments combustibles. Pour ce faire, on enrichit le combustible, ce qui a pour effet d'accroître la probabilité de capture de neutrons avec fission avant leur absorption dans les matières non productives du coeur. C'est l'approche qui a été adoptée dans les réacteurs à eau ordinaire, dans lesquels on utilise des éléments combustibles enrichis en uranium 235. L'enrichissement va jusqu'à 3 % environ dans les PWR et jusqu'à 5 % dans les BWR. La deuxième approche consiste à utiliser du combustible à uranium naturel (0,7 % d'uranium 235, l'abondance isotopique

5) **Les réacteurs à graphite et à eau légère (LWGR — Light-Water Graphite Reactors)** utilisent du graphite comme modérateur; de l'uranium enrichi comme combustible; et de l'eau légère bouillante comme caloporteur. Les LWGR sont des réacteurs de puissance soviétiques, désignés RBMK (Reactor Bolche Molchnastie Kipiache). Les réacteurs de Tchernobyl appartiennent à cette catégorie.

6) **Les réacteurs surrégénérateurs rapides (FBR — Fast Breeder Reactors)** ne possèdent aucun modérateur (de là le nom de surrégénérateur «rapide» parce que les neutrons ne sont pas modérés); utilisent de l'uranium enrichi ou du plutonium comme combustible, et du sodium liquide comme caloporteur. Le principal modèle dans cette catégorie a été le réacteur surrégénérateur rapide refroidi par métal liquide, LMFBR (Liquid-Metal cooled, Fast Breeder Reactor), qui exploitait le cycle uranium 238/plutonium 239. Avec la découverte récente de réserves mondiales d'uranium 235 beaucoup plus grandes que prévu, le sentiment d'urgence qui était rattaché au programme des réacteurs surrégénérateurs a disparu.

Les États-Unis, l'Union soviétique, la France et le Japon ont donné le ton au monde entier en adoptant le type PWR pour la production d'électricité. [L'Union soviétique exploite 23 réacteurs avec modérateur de graphite du type RBMK ainsi que 29 PWR, mais la majorité des réacteurs de puissance soviétiques en construction aujourd'hui sont des PWR.] Comme le révèlent les statistiques compilées dans le World Nuclear Industry Handbook 1988 (NEI, 1988, p. 10 et suivantes), les PWR représentent 60 % des 308 166 millions de watts (308 166 mégawatts ou 308,2 gigawatts) de capacité de production d'électricité installée des 418 réacteurs exploitables dans le monde au 31 juillet 1987. Les PWR dominent de façon encore plus nette le groupe des réacteurs en construction dans lequel ils représentent 75,5 % des 118,6 gigawatts (GW) de capacité de production d'électricité des 130 nouvelles installations en construction.

Le type BWR se classe au deuxième rang parmi les réacteurs exploitables avec 23,5 % de la capacité installée, mais ne représente que 7,4 % de la capacité des réacteurs en construction.

Les GCR constituent une autre gamme de réacteurs en voie de mise au point, dont le principal défenseur a été le Royaume-Uni. Les premières versions britanniques s'appelaient Magnox, tandis que les versions plus récentes s'appellent AGR. [Le sigle «Magnox» se rapporte aux gaines des éléments combustibles à base d'alliage d'oxyde de magnésium.] Les modèles de réacteurs refroidis par gaz, tant anciens que nouveaux, ont une performance médiocre : les réacteurs Magnox n'ont qu'un maigre facteur de charge par rapport à leur capacité de 57,9 % pendant leur durée d'exploitation (à la fin juin 1987), tandis que les niveaux AGR ont un facteur de charge encore plus décevant de 34,8 %. Par contre, le PWR affiche un facteur de charge moyen de 62,7 % pendant sa

La plupart des réacteurs de puissance appartiennent tour à tour à l'un des six principaux types décrits dans la liste qui suit, même s'il existe un grand nombre de variantes de ces modèles de base (Leclercq, 1986, p. 71).

1) **Les réacteurs refroidis par gaz (GCR — Gas-Cooled Reactors)** utilisent du graphite comme modérateur; de l'uranium naturel ou enrichi comme combustible; et du dioxyde de carbone gazeux comme caloporteur. La plupart des premiers GCR étaient du type britannique Magnox ou du type français UNGG (Uranium Naturel, Graphite Gaz); une version plus récente mise au point par les Britanniques est appelée le **réacteur refroidi par gaz perfectionné (AGR — Advanced Gas-cooled Reactor)**.

2) **Les réacteurs à eau lourde (HWR — Heavy Water Reactor)** utilisent de l'eau lourde comme modérateur; de l'uranium naturel, de l'uranium enrichi ou du plutonium comme combustible; et de l'eau lourde sous pression, du dioxyde de carbone gazeux ou de l'eau légère bouillante comme caloporteur. La plupart des réacteurs de cette catégorie sont du modèle CANDU, utilisant de l'eau lourde sous pression comme caloporteur et de l'uranium naturel comme combustible. Ils sont appelés **réacteurs à eau lourde sous pression (PHWR — Pressurized Heavy Water Reactor)**. Le modèle CANDU lui-même est habituellement désigné CANDU-PHWR.

3) **Les réacteurs à eau sous pression (PWR — Pressurized Water Reactor)** utilisent de l'eau légère comme modérateur; de l'uranium enrichi comme combustible; et de l'eau légère sous pression comme caloporteur. Ce type de réacteur fonctionne à des pressions du caloporteur suffisamment élevées pour que l'eau soit maintenue à l'état liquide et traverse un générateur de vapeur pour créer de la vapeur dans un circuit secondaire qui entraîne une turbine. En Union soviétique, ce type est appelé VVER (Vode Vodjanie Energitcheskie Reactor); en France, il est appelé REP (Réacteur à Eau sous Pression).

4) **Les réacteurs à eau bouillante (BWR — Boiling Water Reactors)** utilisent de l'eau légère comme modérateur; de l'uranium enrichi comme combustible; et de l'eau légère bouillante comme caloporteur. Le BWR fonctionne à de faibles pressions du caloporteur, la vapeur se formant dans le circuit primaire de refroidissement pour être acheminée directement vers une turbine. Le BWR est un modèle de réacteur plus simple et moins coûteux que le PWR parce qu'il ne nécessite pas de générateurs de vapeur; par contre, le PWR isole la turbine dans un circuit secondaire, de sorte que la radioactivité s'échappant des éléments combustibles ne contamine pas la turbine.

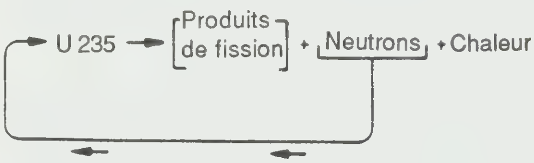
Le terme **réacteur à eau légère (LWR — Light Water Reactor)** est un nom collectif pour les PWR et les BWR.

consomment pendant leur propre fonctionnement. Les réacteurs qui ont un rapport de surrégénération inférieur à l'unité, mais qui produisent néanmoins des quantités importantes de matières fissibles sont souvent appelés des réacteurs «convertisseurs». Le CANDU est un réacteur convertisseur, produisant du plutonium 239 à partir d'uranium 238 pendant son fonctionnement. Il pourrait aussi être exploité comme réacteur quasi surrégénérateur basé sur le cycle du thorium. Les réacteurs qui ne produisent que de petites quantités d'une nouvelle matière fissible sont parfois appelés des réacteurs «à consommation». Les réacteurs à eau légère ont tendance à avoir des facteurs de surrégénération relativement faibles. Comme les réacteurs surrégénérateurs sont aussi employés comme réacteurs de puissance, nous considérerons les surrégénérateurs comme faisant partie d'un sous-ensemble du groupe des réacteurs de puissance.

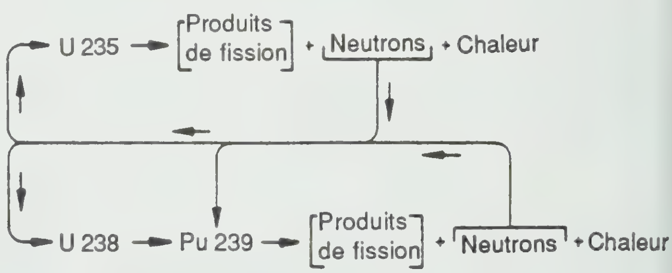
La différence entre la réaction (de puissance) de fission de l'uranium 235 et la réaction de surrégénération de l'uranium 238 est représentée schématiquement dans le graphique 3.

Graphique 3 : Représentation schématique de la réaction de fission de U 235 et de la réaction de surrégénération de U 238

Représentation schématique de la réaction de fission de U 235



Représentation schématique de la réaction de surrégénération de U 238



Source : Hubbert, M. King, "Energy Resources" in *Resources and Man*, National Academy of Sciences-National Research Council, Committee on Resources and Man, W.H. Freeman and Company, San Francisco, 1969, p. 220-221.

de la fission doit répondre à long terme à une part importante des besoins énergétiques de la société, il faudra inclure les réacteurs surrégénérateurs sur cette voie de développement.

La plupart des réacteurs appartiennent à l'une des trois catégories suivantes : les réacteurs de recherche, les réacteurs de puissance et les réacteurs surrégénérateurs. Les **réacteurs de recherche** sont utilisés en général comme sources de neutrons à des fins expérimentales. Ils servent à effectuer des mesures physiques et chimiques, à étudier les effets des neutrons sur des systèmes biologiques et non biologiques, à produire des radionucléides à des fins médicales et industrielles, à étudier l'activation neutronique et à examiner de nouveaux modèles de réacteurs. Un grand nombre de réacteurs de faible puissance sont exploités dans des universités et d'autres établissements de recherche à des fins d'expérimentation et de formation.

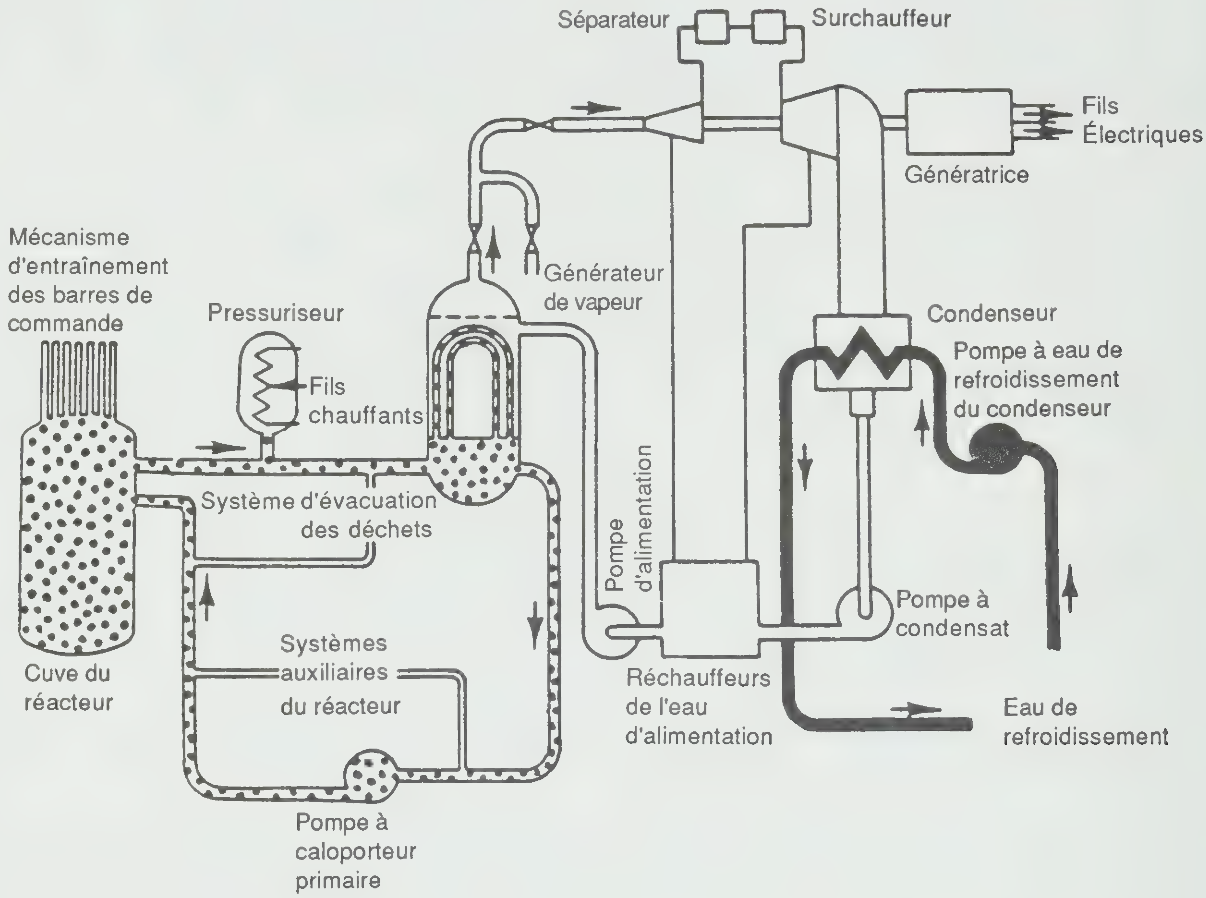
Les **réacteurs de puissance** sont utilisés pour produire de l'électricité, pour produire de la chaleur dans des applications industrielles et de chauffage urbain, pour propulser des navires et des sous-marins (réacteurs souvent appelés «réacteurs de propulsion» dans cette application) et pour des applications aérospatiales. Il y a autant de réacteurs en service dans les marines des États-Unis, de l'Union Soviétique, de la Grande-Bretagne, de la France et de la Chine qu'il y a de réacteurs qui produisent de l'électricité dans les 26 pays du monde où le secteur de la production nucléaire d'électricité a été développé. Les États-Unis, l'Allemagne de l'Ouest et le Japon ont chacun produit un navire marchand propulsé à l'énergie nucléaire (le Savannah américain entré en service en 1962, l'Otto Hahn allemand entré en service en 1968 et le Mutsu-Maru japonais entré en service en 1973), mais tous les trois ont été par la suite retirés à cause de leur profitabilité douteuse et de la difficulté à obtenir la permission de mouiller dans différents ports. L'Union soviétique a construit une série de brise-glace, les plus gros et les plus puissants du monde, qui sont propulsés par des réacteurs nucléaires. De petits réacteurs ont été utilisés pour produire de l'électricité à bord de satellites et de vaisseaux spatiaux. En 1978, le Canada a dû nettoyer les débris radioactifs provenant du satellite atomique soviétique Cosmos qui s'est écrasé dans les Territoires du Nord-Ouest. Un petit réacteur de puissance a déjà été exploité dans une station de recherche américaine de l'Antarctique.

Les **réacteurs surrégénérateurs** convertissent les isotopes fertiles[1] que sont le thorium 232 et l'uranium 238 en isotopes fissibles (artificiels) que sont respectivement l'uranium 233 et le plutonium 239, c'est-à-dire qu'ils «engendrent» des quantités de nouveaux combustibles pour réacteurs supérieures à la quantité de combustible qu'ils

---

1. Un **isotope fertile** est un isotope qui peut être converti en un isotope fissible. L'uranium 238 et le thorium 232, non fissibles en soi, peuvent être convertis par absorption de neutrons en plutonium 239 et en uranium 233, deux isotopes artificiels, respectivement.

Graphique 2 : Représentation schématique des éléments primaires d'un réacteur nucléaire



Source : Tong, L.S. et Joel Weisman, *Thermal Analysis of Pressurized Water Reactors*, deuxième édition, American Nuclear Society, 1979, p. 2.

Il existe trois isotopes naturels de l'uranium : l'uranium 238 qui abonde dans un pourcentage de 99,283 %, l'uranium 235 (0,711 %) et l'uranium 234 (0,006 %). L'uranium 234 est négligeable à cause de sa faible abondance. L'importance de l'uranium 235 réside dans le fait qu'il est, parmi plusieurs centaines d'isotopes naturels, le seul qui est fissible spontanément sous l'effet de la capture de neutrons lents. L'uranium 235 est nécessairement le combustible initial de tout réacteur et, si l'énergie

instantanés», mais aussi une «surcriticité globale», c'est-à-dire que les neutrons instantanés ne peuvent entretenir seuls la réaction en chaîne et que les neutrons retardés assurent la marge de criticité, permettant aux commandes mécaniques de suivre la réaction en chaîne.

Au moins 45 différents isotopes précurseurs de neutrons retardés (fragments de fission qui se désintègrent ultérieurement par émission de neutrons retardés) sont produits dans une réaction de fission en chaîne. Ces précurseurs peuvent être classés en six groupes dont les périodes varient de 0,2 à 55 secondes environ. En général, leur période moyenne est de six secondes environ, marge qui permet un contrôle normal du réacteur.

Les réacteurs refroidis par liquide ont un **coefficient de vide soit positif, soit négatif**. Un coefficient positif signifie que tout événement menant à l'ébullition du caloporteur primaire causera une augmentation de la réactivité et une poussée de la puissance du réacteur. Les réacteurs CANDU ont un coefficient de vide positif de sorte que leurs systèmes d'arrêt doivent être conçus avec soin et réglés par ordinateur pour réaliser un arrêt rapide du réacteur. Un coefficient négatif, caractéristique des réacteurs à eau légère, signifie que l'ébullition du caloporteur primaire entraînera une baisse de réactivité et une chute de la puissance du réacteur.

Environ 4 % de l'énergie de fission libérée est de la chaleur produite par la désintégration de produits de fission radioactifs. Cette chaleur de désintégration continue d'être produite après l'arrêt d'un réacteur. Cette chaleur doit être éliminée pendant l'arrêt sinon la température du coeur du réacteur s'élèvera, entraînant la fusion et la rupture des éléments combustibles.

Les éléments primaires d'un réacteur nucléaire sont représentés sous forme de schéma dans le graphique 2.

Le type de réacteur représenté dans le graphique 2 est le réacteur à eau légère sous pression, modèle le plus répandu à l'étranger. Un circuit primaire de refroidissement, fonctionnant sous haute pression pour empêcher le caloporteur de bouillir, extrait la chaleur du coeur du réacteur et la transporte vers les générateurs de vapeur. Un circuit secondaire de refroidissement fonctionnant sous basse pression extrait la chaleur du caloporteur primaire et transporte la vapeur produite dans les générateurs de vapeur vers des groupes turbine/génératrices pour produire de l'électricité. Un circuit tertiaire de refroidissement utilise l'eau d'une source extérieure comme celle d'un cours d'eau ou d'un lac pour condenser la vapeur qui sort des turbines. Dans une telle configuration, le circuit primaire de refroidissement est isolé, et de l'eau de refroidissement extérieure, et des turbines. Dans ce modèle, de l'eau légère (ordinaire) sert à la fois de caloporteur et de modérateur.

La vitesse de la fission nucléaire doit être contrôlée avec précision à l'intérieur du réacteur pour que la réaction en chaîne puisse être entretenue : une vitesse de fission trop faible met fin à la réaction en chaîne; une vitesse trop élevée libère plus d'énergie que le caloporteur ne peut en dissiper. Si le nombre de fissions augmente, la puissance augmente et le réacteur est dit **sur-critique**. Si le nombre de fissions diminue, le réacteur est **sous-critique**. La vitesse de fission et le niveau de puissance demeurent constants lorsque le réacteur est au niveau **critique**. La **réactivité** est une mesure de l'écart d'un réacteur par rapport à un état critique. Une réactivité positive signifie que le flux de neutrons dans le coeur du réacteur augmente et que le niveau de puissance augmente également; une réactivité négative signifie que le flux de neutrons diminue et que le niveau de puissance diminue également.

Des **barres de commande** constituées d'une matière qui absorbe les neutrons, telle que le cadmium, sont utilisées pour varier la vitesse de la réaction. En retirant ou en enfonçant les barres de commande dans le coeur du réacteur, on modifie le nombre de neutrons disponibles pour entretenir la réaction en chaîne. Les barres de commande peuvent être enfoncées complètement pour arrêter la réaction nucléaire. Un réacteur peut aussi être équipé d'un système qui introduit un poison dans le noyau. Un poison est une substance non fissible dont la capacité de capturer des neutrons, et donc de diminuer la réactivité (arrêter la réaction en chaîne), est élevée.

Dans certaines circonstances, notamment pendant un accident grave de perte de caloporteur, il peut arriver que les systèmes normaux de commande du réacteur ne puissent maîtriser la situation. Dans ces rares cas, on peut faire intervenir des systèmes de sûreté additionnels tels qu'un **système de refroidissement de secours du coeur (SRSC) et une enveloppement de confinement** du réacteur pour diminuer les conséquences d'un accident. Le refroidissement d'urgence du coeur est assuré par un système conçu pour injecter de grandes quantités d'eau froide dans le circuit caloporteur après une perte importante de caloporteur. L'enveloppe de confinement primaire est la structure de béton renforcée qui loge le réacteur et ses systèmes immédiats. Sa fonction est de confiner la radioactivité en cas de rupture du coeur du réacteur lors d'un accident grave.

Des systèmes de commande mécaniques seraient incapables de contrôler un réacteur si la fission était seulement une fonction du temps nécessaire au modérateur pour ralentir les neutrons rapides à des vitesses thermiques (de l'ordre d'une milliseconde à 10^{-3} seconde). La plupart des neutrons sont émis instantanément pendant la fission elle-même, et ils sont appelés **neutrons instantanés**. Un petit pourcentage (moins de 1 %) des neutrons sont émis par la suite par les produits de fission, après une ou plusieurs désintégrations bêta et un temps appréciable; ces neutrons sont appelés **neutrons retardés**. Le nombre total de neutrons disponibles pour entretenir la fission est égal à la somme des neutrons instantanés et des neutrons retardés. L'un des objectifs dans la conception d'un réacteur est de réaliser une «sous-criticité avec les neutrons

maintenir les éléments de masse sous-critique ensemble. Un dispositif d'injection de neutrons est utilisé pour augmenter la réactivité. Un réacteur ne peut supporter une explosion nucléaire à cause de la géométrie du coeur, du faible niveau d'enrichissement du combustible du réacteur (ou du manque d'enrichissement, comme dans CANDU) et de la présence de matières qui absorbent les neutrons, comme l'uranium 238, dans les éléments combustibles.

Les neutrons sont expulsés des atomes en fission à une vitesse élevée. Pour que la réaction se propage dans un réacteur nucléaire, les neutrons doivent être ralentis de façon à être capturés par d'autres atomes fissibles. La fonction du **modérateur** est de ralentir les neutrons «rapides» sans les absorber (c'est-à-dire que le modérateur doit avoir une «petite section efficace de capture neutronique»). Lorsque les neutrons sont ralentis de façon que leur énergie cinétique approche le niveau d'énergie thermique, la section efficace de capture neutronique de la matière fissible augmente considérablement, et une réaction en chaîne peut ensuite être entretenue par les neutrons «lents»[1]. Le meilleur modérateur est «l'hydrogène lourd» ou le deutérium, un isotope de l'hydrogène dont le noyau comporte un neutron et un proton. Comme l'hydrogène est difficile à manipuler dans sa forme élémentaire (se rappeler de l'explosion du dirigeable allemand *Hindenburg* en 1937), on utilise habituellement de l'eau comme modérateur, l'oxygène ayant également une petite section efficace. L'eau lourde (D_2O), l'eau ordinaire (H_2O), et le carbone (sous la forme de graphite) et le béryllium à l'état solide sont les modérateurs les plus répandus.

La libération d'énergie par fission produit de grande quantité de chaleur. Par conséquent, un milieu appelé **caloporteur** doit circuler dans le coeur du réacteur pour en éliminer la chaleur. Le caloporteur sert aussi de milieu de transfert de chaleur dans un réacteur utilisé pour la production d'électricité, acheminant l'énergie thermique vers un échangeur de chaleur où elle est communiquée à un circuit de vapeur qui entraîne à son tour une turbine pour produire de l'électricité. Comme le caloporteur traverse le coeur du réacteur, il doit supporter des températures élevées et des rayonnements intenses. Les bons caloporteurs sont l'eau (légère et lourde), certains liquides organiques (notamment une classe d'huiles légères appelées terphényles aromatiques), certains métaux liquides (notamment le sodium) et certains gaz, notamment le dioxyde de carbone et l'hélium.

---

1. Un **isotope fissible** dans le présent contexte s'entend d'un isotope dont la fission peut être provoquée par des neutrons lents ou de faible énergie. Il n'existe que trois isotopes fissibles importants : l'uranium 235 qui est un isotope naturel, le plutonium 239 et l'uranium 233 qui sont des isotopes artificiels.

Des forces électriques puissantes retiennent les atomes du noyau ensemble. Lorsque ces forces nucléaires sont libérées, la quantité d'énergie produite est énorme. La **fission** est une réaction nucléaire qui consiste en la scission en deux parties (à l'occasion en trois parties) d'un noyau lourd avec libération d'énergie et d'au moins deux neutrons. La fission peut être spontanée — comme c'est le cas de la désintégration des substances radioactives — ou induite par bombardement par des particules telles que les neutrons (c'est le processus exploité dans un réacteur nucléaire). La fission d'un kilogramme d'uranium 235 dans un réacteur nucléaire libère à peu près la même quantité d'énergie que la combustion de 2 800 tonnes de charbon. L'énergie atomique est produite par des réactions à l'intérieur même du noyau de l'atome, alors que la chaleur libérée par la combustion du charbon est le produit de réactions chimiques qui ne font intervenir que les électrons entourant l'atome.

Voici en quelques mots en quoi consiste la réaction de fission :

Neutron + noyau fissible ⟶ noyaux des produits de fission + neutrons
+ électrons bêta + photons gamma.

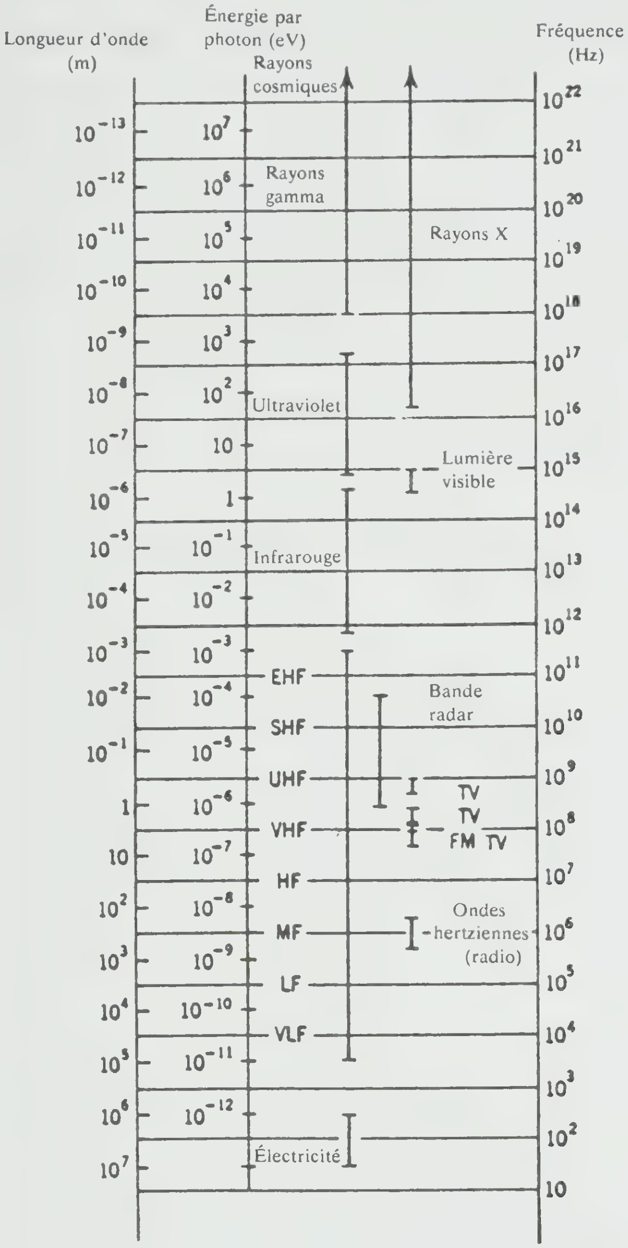
Pour les besoins de la présente discussion, un isotope fissible est un isotope dont la fission peut être provoquée par des neutrons.

Dans la conception des réacteurs nucléaires servant à la fabrication d'électricité, le processus dont l'importance est primordiale est la **réaction en chaîne**. Ce qui rend possible la production d'électricité dans un réacteur à fission nucléaire est le fait que 2,5 neutrons sont émis, en moyenne, pour la fission de chaque atome d'uranium 235. La fission d'un atome de plutonium 239 libère en moyenne trois neutrons. La réaction s'entretient d'elle-même lorsqu'un des neutrons au moins peut être capturé par un autre atome, ce qui provoque une autre fission et entretient la réaction en chaîne.

B. Conception et utilisation des réacteurs

Un **réacteur** nucléaire est un assemblage de matière fissible dans lequel une fission nucléaire peut être entretenue sous la forme d'une réaction en chaîne contrôlée et auto-entretenue. Le coeur du réacteur qui contient cet assemblage peut être vu comme un four dans lequel la matière fissible se consume, avec libération contrôlée de chaleur. La première réaction en chaîne auto-entretenue a été réalisée dans un assemblage d'uranium naturel avec modérateur de graphite, à l'Université de Chicago, le 2 décembre 1942. Même si les armes nucléaires et les réacteurs nucléaires exploitent tous les deux le principe de la réaction en chaîne dans leur fonctionnement, l'excédent de réactivité d'une arme nucléaire est énorme, lui permettant de libérer une formidable quantité d'énergie dans un temps extrêmement court. Pour réaliser cette condition, la bombe doit comporter une matière fissible de grande pureté et un déclencheur pour

Graphique 1 : Le spectre électromagnétique



Source: Eisberg, Robert and Robert Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*, John Wiley & Sons, Toronto, 1974, p. 38.

Le **rayonnement électromagnétique** est l'émission ou le transfert d'énergie sous forme d'ondes électromagnétiques ou de particules. Le spectre électromagnétique va des ondes radio les plus longues aux rayons gamma les plus courts, les différents rayonnements se distinguant par leur fréquence de vibration. Dans notre société, le spectre électromagnétique est utilisé à diverses fins : la transmission de l'électricité dans des fils à une fréquence typique de 50 ou de 60 cycles à la seconde (50 ou 60 hertz), la radiodiffusion et la télédiffusion, le radar, les rayons X (pour le traitement du cancer) et même pour le bronzage de la peau (avec les risques d'induction d'un cancer cutané qui s'y rattachent). La lumière perceptible par l'oeil fait partie de ce spectre.

Le graphique 1 est une illustration du spectre électromagnétique et des emplois faits des diverses bandes d'énergie.

La décroissance radioactive s'accompagne de la libération d'au moins un des quatre types de rayonnements suivants qui sont capables d'endommager les tissus vivants : particules alpha, particules bêta, rayons gamma et neutrons. Une particule **alpha** est un noyau d'hélium chargé positivement (deux protons et deux neutrons) éjecté du noyau d'un atome instable. Une particule **bêta** est un électron chargé négativement émis par le noyau d'un atome pendant sa désintégration. Le rayon **gamma** est la quantité spécifique d'un rayonnement électromagnétique (photon) émise par un atome par suite d'une transition d'un niveau d'énergie excité à un niveau inférieur. Les rayons gamma n'ont aucune masse ni aucune charge.

Le pouvoir pénétrant des rayons bêta est environ 100 fois celui des rayons alpha; pour leur part, les rayons gamma sont 10 000 fois plus pénétrants que les rayons alpha. Ces quatre types de rayonnements étant capables d'ioniser la matière qu'ils traversent, ils constituent par conséquent un danger biologique. Chez les humains, ils peuvent avoir des effets somatiques — des effets physiques apparents — ou des effets génétiques — sur les enfants des personnes exposées aux rayons. Les émetteurs alpha, tels le plutonium et le radon gazeux, sont très dangereux lorsqu'ils sont ingérés ou inhalés. Étant donné leur pouvoir pénétrant plus grand, les émetteurs bêta et gamma sont dangereux pour les humains tant de façon interne que de façon externe. L'exposition à des neutrons de grande énergie constitue habituellement un risque uniquement dans certains environnements de travail avoisinant un réacteur. Ces quatre types de rayonnements peuvent aussi être absorbés (comme la chaleur) dans des matériaux constituant un blindage comme le plomb, le béton ou l'eau.

Des radionucléides artificiels sont créés dans les réacteurs nucléaires et les accélérateurs de particules lorsque des atomes sont bombardés avec des particules de grande énergie. Leur comportement est le même que ceux des radionucléides naturels. Par exemple, le plutonium 239 qui est créé dans un réacteur nucléaire commence aussitôt à se désintégrer selon la période caractéristique de cet élément, soit environ 24 360 années. La séquence de réactions nucléaires qui entraînent la formation de plutonium dans le réacteur est la suivante :

uranium 238 + neutron ⟶ uranium 239 + rayon gamma

uranium 239 ⟶ neptunium 239 + particule bêta

neptunium 239 ⟶ plutonium 239 + particule bêta

Le plutonium se désintègre ensuite en émettant une particule alpha, donnant un isotope stable du plomb.

l'uranium, dont trois existent dans la nature; parmi les 1 700 nucléides (et davantage) qui sont connus, il en est donc 15 qui sont des formes de l'uranium.

Certains éléments — qui ont généralement un nombre de masse élevé — sont instables et se désintègrent ou «décroissent» naturellement. La **radioactivité** est la désintégration ou la fission spontanée du noyau d'un atome instable avec libération d'énergie. Cette décroissance spontanée ne se fait pas au hasard : elle se produit à une vitesse spécifique qui est propre à chaque nucléide radioactif (radionucléide). L'unité choisie pour mesurer la radioactivité («activité») est le becquerel. Un becquerel (abréviation Bq) correspond à une désintégration radioactive par seconde[1].

La **période** (ou demi-vie) d'un radionucléide est le temps nécessaire pour que son activité (par conséquent le nombre d'atomes non désintégrés) ait diminué de 50 %. Après une période, il reste la moitié de la substance originale et la moitié de sa radioactivité originale; après deux périodes, seulement le quart; et après 10 périodes, seulement 1/1024. La période varie énormément d'un radionucléide à l'autre : pour l'oxygène 13 (un radionucléide produit de façon artificielle) elle est de 0,0087 seconde; par contre, dans le cas du vanadium 50 (un radionucléide naturel) elle est de l'ordre de 6 000 billions (6×10^{15}) d'années. Voici quelques exemples plus courants : la période du tritium (hydrogène 3) est de 12,4 années; celle de l'uranium 238, de 4,51 milliards d'années.

Il existe quatre séries naturelles de désintégration radioactive des éléments lourds, soit la série du thorium, la série du neptunium, la série de l'uranium et la série de l'actinium. La série du neptunium ne s'observe plus dans la nature, car l'élément de cette série ayant la période la plus longue (le neptunium 237 dont la période est de 2,2 millions d'années) a essentiellement fini de se désintégrer depuis son apparition dans l'univers il y a quelque 15 milliards d'années. Par contre, l'uranium 238 n'a même pas encore traversé quatre périodes de désintégration depuis l'époque (calculée) de la création de l'univers. Il existe aussi un certain nombre de radionucléides naturels isolés qui n'appartiennent pas à l'une des chaînes de décroissance des éléments lourds. Les plus remarquables sont le tritium et le carbone 14 (qui sont continuellement créés par le bombardement de l'atmosphère terrestre par des rayons cosmiques), le potassium 40 et le rubidium 87. Un certain nombre des radionucléides naturels servent à la datation en géologie et en archéologie.

---

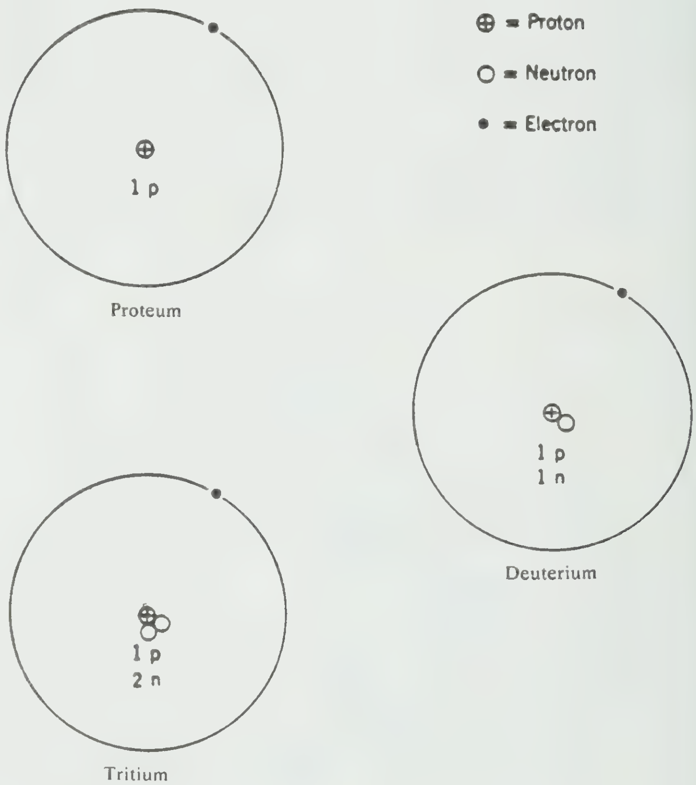
1. Le becquerel a remplacé le curie comme unité de mesure de la radioactivité. Par définition, le curie est la mesure de la radioactivité d'un gramme de radium soit 3,7 x 10 désintégrations par seconde. Comme le becquerel est la mesure d'une radioactivité correspondant à une désintégration (ou décroissance) par seconde, le rapport entre les deux unités est le suivant : un curie = 37 milliards de becquerels et un becquerel = $2{,}7 \times 10^{-11}$ curie.

La somme du nombre de protons et du nombre de neutrons d'un atome constitue son **nombre de masse**.

À leur état élémentaire, les atomes contiennent un nombre égal de protons et d'électrons; leur charge électrique nette est donc nulle. Dans certaines circonstances, les atomes peuvent gagner ou perdre des électrons, prenant ainsi une charge négative ou positive. On dit alors qu'ils sont ionisés. Les rayonnements capables d'arracher des électrons aux atomes sont dits **rayonnements ionisants**.

C'est le nombre de protons qu'il renferme qui détermine le **numéro atomique** d'un élément ainsi que sa position dans le tableau périodique. Un atome qui ne renferme qu'un seul proton est toujours de l'hydrogène; si ce nombre est huit, il s'agit d'oxygène; et lorsque l'atome contient 79 protons, c'est de l'or. Toutefois, le nombre de neutrons présents dans le noyau de chaque élément peut varier; ces différentes versions d'un même élément sont ce qu'on appelle des isotopes.

Par exemple, le noyau d'hydrogène renferme la plupart du temps un proton et aucun neutron; sous cette forme, il est appelé protium. Il peut cependant renfermer un proton et un neutron et on le nomme alors deutérium. Lorsque le noyau d'hydrogène renferme un proton et deux neutrons, il s'agit de la forme instable dite tritium. Les **isotopes** sont des atomes qui ont le même numéro atomique, mais des nombres de masse différents. Il est possible de mettre en évidence la différence entre les divers isotopes de l'hydrogène en écrivant : hydrogène-1 (H-1), H-2 et H-3 (c'est-à-dire en donnant le nom de l'élément, puis son nombre de masse). L'U-235 est l'isotope de l'uranium qui sert de combustible initial dans un réacteur nucléaire.



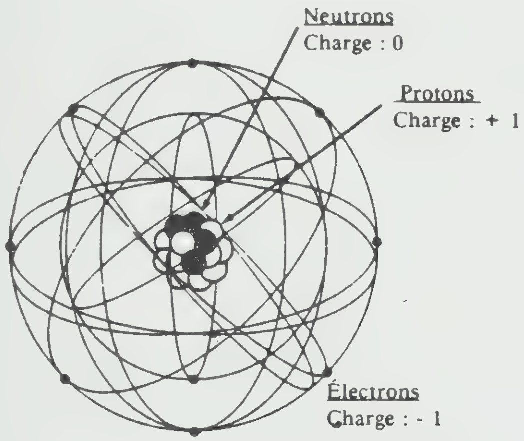
Chaque isotope des divers éléments constitue une espèce atomique individuelle et chaque espèce atomique est dite **nucléide**. Il y a quelque 104 éléments naturels et artificiels connus. Toutefois, si l'on fait la somme du nombre de tous leurs isotopes, on s'aperçoit qu'il y a plus de 1 700 nucléides. Par exemple, il existe 15 isotopes connus de

LES RÉACTEURS

A. La physique nucléaire

Toute matière — qu'elle soit solide, liquide ou gazeuse — se compose d'**atomes**, des petites «particules» qui sont perpétuellement en mouvement. Le rayon de la plupart des atomes mesure moins de 2×10^{-8} centimètre (0,00000002 centimètre). L'unité de mesure correspondant à 10^{-8} cm s'appelle l'angström; le rayon de l'atome type mesure donc moins de 2 angströms. Si une pomme était grossie aux dimensions de la Terre, les atomes de cette pomme auraient à peu près la grosseur de la pomme originale.

Une fois que les scientifiques eurent établi que toute matière se compose de particules ou d'atomes, il était naturel pour eux de se demander combien de sortes de particules — **éléments** — il y avait dans la nature. Quatre-vingt-onze éléments ont été découverts dont le numéro atomique va jusqu'à 94 (trois éléments de la séquence n'existent pas dans la nature). L'hydrogène (H), qui est l'atome le plus simple, a reçu le numéro atomique 1 et l'uranium (U), l'élément au coeur des centrales nucléaires, le numéro atomique 92. En plus des éléments naturels, la science a permis de découvrir environ une douzaine d'éléments artificiels produits par des réactions nucléaires. Tous ces éléments fabriqués par l'homme sont instables et se transforment tôt ou tard en un élément plus léger qui est stable.



Les atomes eux-mêmes se composent de trois particules plus fondamentales : les protons, les neutrons et les électrons. Au centre de l'atome, un petit noyau renferme des **protons** qui sont chargés positivement et des **neutrons** qui sont électriquement neutres. Les protons et les neutrons sont beaucoup plus lourds que les particules du troisième type, soit les **électrons** qui ont une charge négative et qui peuvent être représentés en mouvement dans un nuage sphérique autour du noyau. Le noyau constitue uniquement environ 10^{-15} du volume de l'atome, mais presque toute sa masse, comme c'est le cas du Soleil dans notre système planétaire.

L’énergie atomique n’est pas un mauvais génie. Traitée avec respect et bien gérée, il s’agit d’une source d’énergie extrêmement prometteuse pour l’avenir de la société. Le programme nucléaire du Canada est bien conçu et bien exploité. À condition qu’on s’attache bien à corriger les lacunes constatées par le Comité, l’énergie nucléaire aura certainement à jouer un rôle accru dans le bilan énergétique du Canada au cours du XX^{e} siècle.

L'économie de l'énergie et la modification de la demande d'électricité sont deux facteurs dont il y a lieu de tenir compte dans la planification des installations de production, mais à long terme il semble peu vraisemblable qu'ils influeront sur plus qu'une fraction de la hausse de la demande. L'économie de l'énergie et la modification de la demande soulageront en effet les pressions incitant à construire de nouvelles centrales, et devraient en conséquence être de pratique généralisée, mais elles ne constituent pas une solution complète. Le gouvernement fédéral doit promouvoir des mesures d'utilisation plus efficaces de l'électricité, quand ces mesures sont rentables et profitables à toutes les parties intéressées, mais il ne doit pas présumer que de telles mesures supprimeront entièrement le besoin d'augmenter la capacité de production.

14. Le Comité recommande aux gouvernements fédéral et provinciaux de travailler en étroite collaboration pour déterminer les possibilités d'utilisation plus efficace de l'électricité et pour promouvoir des mesures qui favoriseront un meilleur rendement économique.

La production d'électricité par le secteur privé est une autre avenue qui permettrait de réduire le fardeau qu'imposerait aux compagnies publiques d'électricité le financement de nouvelles installations de production. Étant donné la dette croissante à long terme qui pèse sur le bilan des compagnies publiques d'électricité au Canada, presque 50 milliards de dollars au total pour les deux principales compagnies du Canada, il y a lieu d'aplanir les obstacles inutiles à la production d'électricité par le secteur privé, de sorte que des producteurs privés puissent se faire concurrence. Que la production d'électricité par le secteur privé joue ou non un rôle substantiel dépendra pour beaucoup de la conjoncture de chacune des compagnies d'électricité, mais en principe le Comité est favorable à une augmentation de la production d'électricité par le secteur privé.

Le Comité souligne que le gouvernement de l'Ontario a demandé que la province soit l'hôte du Réacteur expérimental thermonucléaire international. Ce réacteur expérimental est en fait un grand réacteur de fusion d'essai, dont on dit qu'il constitue la prochaine grande étape dans le développement de la technologie de la fusion, et est un projet qu'envisagent en commun les États-Unis, l'Union Soviétique, la Communauté européenne et le Japon. Beaucoup d'arguments plaident en faveur de l'Ontario. La centrale Bruce, sur la rive du lac Huron, constitue à la fois un excellent site et une source d'électricité qui permettrait de faire fonctionner le réacteur de fusion. L'Ontario Hydro peut par ailleurs fournir le tritium nécessaire à alimenter la fusion. En contrepartie, les avantages dans les domaines de la R et D, de l'ingénierie et de la construction technique du réacteur seraient extrêmement profitables au Canada. La Finlande et l'Allemagne de l'Ouest auraient également posé leur candidature à titre d'hôte du projet.

profil public plus visible, par exemple en admettant le grand public à toutes ses audiences. Le Comité entérine la recommandation du rapport Hare portant sur le renforcement des comités consultatifs de la CCÉA. Enfin, le Comité recommande de changer le nom de la CCÉA, qui pourrait s'appeler par exemple Commission de réglementation du nucléaire, de sorte que le public la distingue plus facilement de l'ÉACL.

10. Le Comité recommande de porter d'un à cinq le nombre de membres à plein temps de la CCÉA, tout en maintenant les quatre postes à temps partiel.

11. Le Comité recommande à la Commission de contrôle de l'énergie atomique d'adopter un profil public plus visible, et notamment d'admettre le grand public à toutes ses audiences.

12. Le Comité recommande enfin de changer le nom de la Commission de contrôle de l'énergie atomique (CCÉA), de sorte que le grand public la distingue plus facilement de l'Énergie atomique du Canada, Limitée (ÉACL).

Il faut manifestement éduquer le public canadien à propos des avantages et des coûts de l'énergie nucléaire. Pour sa majeure partie, le débat public portant sur le développement du nucléaire est faussé, et il est dans les intérêts de chacun que la situation soit corrigée. Le Comité estime que cette tâche devrait être confiée à un organisme fédéral qui connait bien le sujet, mais qui ne s'occupe pas de la promotion de l'énergie nucléaire. Le Comité pense que la CCÉA pourrait être cet organisme.

13. Le Comité recommande d'ordonner à la Commission de contrôle de l'énergie atomique de créer un bureau d'éducation du public dont le rôle serait de renseigner objectivement le public canadien sur le développement du nucléaire. Le gouvernement du Canada devra veiller à ce que la CCÉA reçoive des crédits suffisants pour lui permettre d'accomplir cette tâche efficacement.

Le coût de la réglementation de l'industrie nucléaire est comparativement élevé, même au Canada où la réglementation nucléaire est beaucoup moins imposante et contraignante qu'aux États-Unis. La raison est que la société impose des normes sans pareilles à la production de l'énergie nucléaire et à la gestion des déchets radioactifs. Ces normes sont beaucoup plus rigoureuses que celles qu'on applique à l'exploitation des autres filières énergétiques et à la manutention des autres substances toxiques, mais elles sont nécessaires pour rassurer le public. Il n'en demeure pas moins qu'il faut tenter de réaliser l'équilibre optimal entre la réglementation et les coûts de la réglementation. L'ÉACL devrait chercher à exploiter les possibilités qui existent d'appliquer la technologie mise au point pour la gestion des déchets radioactifs à la gestion d'autres substances toxiques.

accru. Il est essentiel que l'industrie nucléaire et que l'industrie connexe des radionucléides soient bien réglementées pour garantir leur exploitation sûre, et aussi pour que le grand public soit convaincu que les activités de ces industries sont bien réglementées.

Le Comité recommande de modifier la législation relative à la Commission de façon à permettre à cette dernière de pratiquer une quelconque forme de recouvrement des coûts, notamment dans le domaine de la délivrance des permis. Compte tenu du fait que le recouvrement des coûts ne permettra pas à la Commission de se garantir suffisamment de revenus pour s'acquitter entièrement de ses responsabilités, le Comité recommande également d'ajuster les crédits votés par le Parlement de manière à combler le manque à gagner. Une augmentation du soutien accordé à la CCÉA aurait pour effet d'accélérer l'étude des demandes de permis et permettrait à la Commission d'étudier plus à fond les présentations des demandeurs. La CCÉA a également besoin de ressources accrues pour étendre son programme de recherche en matière de réglementation. Le Comité constate dans cette perspective que la U.S. Nuclear Regulatory Commission a été mandatée par le Congrès de récupérer 45 % de son budget de 1988/1989 de 392,8 millions de dollars US, par l'imposition de frais aux utilisateurs. [Les crédits votés par le Parlement à la CCÉA pour l'exercice financier 1988-1989 sont de 24,4 millions de dollars.]

8. Le Comité recommande de modifier la *Loi sur le contrôle de l'énergie atomique* de sorte que la Commission de contrôle de l'énergie atomique puisse pratiquer le recouvrement des coûts par l'imposition de droits de permis et de frais pour d'autres services, pourvu que ces droits et frais ne gênent pas indûment la diffusion de l'information auprès du public par la Commission.

Le témoignage de la CCÉA, l'étude récente du Dr Hare sur la sûreté des réacteurs en Ontario et d'autres sources d'information indiquent que la Commission est substantiellement à court de ressources financières et humaines. Le Comité reconnaît le fait et doute que le recouvrement des coûts à lui seul puisse financer une mission élargie de la Commission.

9. Le Comité recommande donc en outre au Parlement, dans la mesure où le recouvrement des coûts institué par la Commission de contrôle de l'énergie atomique ne suffise pas à financer son exploitation, de voter à la Commission des crédits accrus afin de s'assurer que cette dernière puisse s'acquitter entièrement et rapidement de toutes ses responsabilités.

Il y a aussi lieu de se pencher sur d'autres aspects de l'exploitation de la CCÉA. Le Comité recommande de porter d'un à cinq le nombre de membres à plein temps de la CCÉA. Cette mesure permettrait une meilleure représentation des divers secteurs de spécialisation à la Commission et la placerait dans une meilleure position pour traiter un volume accru de travail. Le Comité recommande à la Commission d'adopter un

commercialisation. Le Comité n'arrive pas à comprendre pourquoi cet atout n'a pas été mieux exploité. Les Français et les Allemands de l'Ouest ont su profiter d'un tel avantage, et permettent l'autorisation générique par leurs organismes de réglementation.

Le Comité incite les gouvernements du Canada et du Nouveau-Brunswick à s'entendre sur la construction d'un nouveau réacteur CANDU 300 à Point Lepreau. Ce projet pourrait servir à démontrer les gains de temps que permet l'autorisation générique. Cela pourrait toutefois être extrêmement difficile, à moins qu'on ne remédie à l'actuelle pénurie de main-d'oeuvre de la CCÉA.

Le gouvernement fédéral envisage de privatiser deux divisions de l'ÉACL dans un proche avenir : la Société radiochimique et la Division des produits médicaux. La Société radiochimique produit des radionucléides et des irradiateurs destinés à des fins médicales et industrielles, tandis que la Division des produits médicaux commercialise du matériel de radiothérapie. Le Comité fait sien l'objectif de la privatisation, mais s'inquiète du fait que l'ÉACL ne posséderait plus qu'une équipe centrale de recherche fondamentale et appliquée qui ne peut être autosuffisante. Compte tenu de la réduction parallèle des crédits fédéraux à la recherche et au développement nucléaires, cette mesure, de l'avis du Comité, aurait pour effet de paralyser l'effort de recherche nécessaire au soutien du développement du nucléaire au Canada et à la production de la prochaine génération de réacteurs. Il se pourrait ainsi que personne ne prenne la relève d'importants et prometteurs travaux de R et D, comme la recherche sur le dépistage du cancer menée à Chalk River.

Le Comité recommande donc à l'ÉACL de conserver un intérêt minoritaire dans la Société radiochimique, dans la Division des produits médicaux et dans les diverses unités commerciales qui seront privatisées. La mesure permettra d'une part à l'ÉACL de s'assurer un revenu modeste mais régulier, et d'autre part à la nouvelle entité de garder un lien de R et D avec une société reconnue internationalement, lien qui pourrait être précieux pour le développement de futurs produits. Le Comité recommande enfin au gouvernement de prévoir des dispositions qui interdiraient aux étrangers de détenir plus qu'un intérêt minoritaire dans ces sociétés.

6. **Le Comité recommande de modifier le mandat législatif de l'Énergie atomique du Canada, Limitée, afin de permettre à la société de détenir un intérêt minoritaire dans tout secteur actuel qui sera privatisé.**

7. **Le Comité recommande aussi de garder obligatoirement sous contrôle canadien toute nouvelle entité créée par la privatisation de l'Énergie atomique du Canada, Limitée, bien que des étrangers puissent détenir un intérêt minoritaire.**

La Commission de contrôle de l'énergie atomique, qui réglemente les activités nucléaires au Canada, est manifestement à court de ressources humaines et financières pour s'acquitter même de ses actuelles responsabilités, sans parler d'un éventuel rôle

l'avenir, et les compagnies d'électricité qui ont tant profité des travaux de l'ÉACL pourraient être en position d'augmenter leur aide financière. Cependant, même si tel était le cas, il n'y a pas lieu de réduire les crédits du gouvernement fédéral. Le Comité conclut que le gouvernement fédéral doit accroître les crédits qu'il verse à l'ÉACL et les maintenir à un niveau élevé pendant au moins cinq à dix ans, afin de garantir la stabilité financière de cette société de la Couronne pendant qu'elle travaille à commercialiser ses divers produits et à mieux s'autofinancer. En aucun cas, le manque de crédits ne doit compromettre l'intégrité de l'actuel programme des réacteurs.

4. Le Comité recommande au gouvernement du Canada d'accroître les crédits qu'il verse à l'Énergie atomique du Canada, Limitée, et de maintenir les crédits à leur nouveau niveau pendant au moins cinq ans.

L'ÉACL est le premier établissement de «sciences lourdes» du Canada. Ses compétences scientifiques et techniques constituent une ressource nationale qu'il a fallu un peu plus de 40 ans à constituer. Il faut encourager l'Énergie atomique du Canada, Limitée à poursuivre sa diversification dans de nouveaux domaines scientifiques et techniques, et à se doter d'un programme de sensibilisation lui permettant de convaincre le public de l'importance de sa mission.

5. Le gouvernement du Canada doit encourager l'Énergie atomique du Canada, Limitée, un des principaux établissements scientifiques du pays, à accroître ses travaux de recherche et de développement dans le domaine nucléaire et non nucléaire.

L'ÉACL a toutefois tardé à réagir au ralentissement des ventes de réacteurs sur les marchés national et international. Bien qu'elle s'évertue maintenant à diversifier ses activités au sein du secteur nucléaire, un temps précieux a été perdu. Il ressort manifestement des études du Comité qu'il se vendra beaucoup moins de réacteurs sur le marché international, pendant quelque temps, et qu'en conséquence l'ÉACL, Framatome, Westinghouse, General Electric, Kraftwerk Union et d'autres fournisseurs se livreront une lutte acharnée. L'ÉACL ne pourra pas survivre que de la vente de réacteurs et devra en conséquence diversifier ses activités. Le gouvernement fédéral doit l'encourager à le faire le plus rapidement possible.

Il faut s'y prendre beaucoup d'avance pour construire un réacteur nucléaire et consentir d'importants investissements initiaux. La prévision de la demande future d'électricité étant entachée d'une certaine incertitude, les compagnies d'électricité ne décident de construire de nouvelles centrales qu'avec une extrême prudence. Étant donné également la montée des coûts qu'entraîne tout retard dans la construction, il est impératif que les réacteurs futurs puissent être construits en beaucoup moins de temps, comme c'est le cas couramment en France et au Japon, par exemple. Il faut donc trouver le moyen d'accélérer le processus conception-autorisation-construction. La conception normalisée du réacteur CANDU aurait dû constituer un important atout de

Les caractéristiques de sûreté du réacteur CANDU et l'intégration dans la conception d'une «défense en profondeur» garantissent que ce réacteur puisse être exploité au Canada avec un risque minime tant pour le personnel des compagnies d'électricité que pour le grand public. Rien dans les témoignages que le Comité a entendus ou dans les renseignements qu'il a obtenus dans ses déplacements ne permet de contester ce jugement.

Par contre, le Comité constate que les limites de responsabilité civile des installations nucléaires canadiennes sont insuffisantes et qu'elles doivent être relevées. Le maximum actuel, 75 millions de dollars dans le cas d'une centrale à plusieurs réacteurs comme Pickering A/B ou Bruce B, est tout simplement trop bas. Les fournisseurs nucléaires n'ont quant à eux aucune responsabilité. Bien qu'il ne soit pas en mesure de préciser quelles devraient être les limites de responsabilité civile, le Comité fait observer que les actuelles limites ne sont ni réalistes, quand on songe que les réclamations consécutives à l'incident de Three Mile Island ont dépassé le milliard de dollars et que les dommages produits par l'accident de Tchernobyl seraient bien supérieurs à 2 milliards de dollars, ni comparables aux limites établies dans des pays comme l'Allemagne de l'Ouest et les États-Unis. Le fait que la possibilité d'un accident grave au cours duquel des quantités dangereuses de matières radioactives seraient émises dans l'environnement soit extrêmement mince ne signifie pas que le Canada ne doit pas se préparer à un tel événement.

3. Le Comité recommande d'accroître substantiellement l'assurance responsabilité civile de base des installations nucléaires du Canada.

L'organisme moteur du développement du nucléaire au Canada est l'Énergie atomique du Canada, Limitée. L'ÉACL a exécuté et continuera d'exécuter la plupart des travaux de R et D qui sont à l'origine de la conception, du développement et de la sûreté des réacteurs canadiens. Cette société de la Couronne a également pour mission de commercialiser la technologie nucléaire canadienne à l'étranger. À l'instar des autres fournisseurs internationaux, elle se ressent financièrement du ralentissement mondial survenu dans la construction de nouveaux réacteurs de puissance. Parallèlement, le gouvernement fédéral se propose de réduire par étapes les crédits de l'ÉACL, jusqu'à concurrence d'un total de 100 millions par année.

Il est toutefois inopportun pour le gouvernement fédéral de réduire les crédits qu'il fournit à l'ÉACL, pour l'instant. Ainsi que l'en ont convaincu les témoignages que le Comité a entendus et comme le souligne le D^{r} Hare dans son étude, cette réduction des crédits de l'ÉACL empêche la société de fournir la R et D nécessaires aux compagnies d'électricité qui exploitent l'électronucléaire pour poursuivre l'exploitation sûre et fiable de leurs réacteurs de puissance. Ce support en matière de R et D doit nécessairement se poursuivre de façon continue, tant et aussi longtemps que les réacteurs sont exploités. L'ÉACL pourrait être en mesure de mieux s'autofinancer à

1. **Le Comité recommande d'accélérer l'ensemble du programme portant sur l'établissement d'un site commercial d'enfouissement des déchets hautement radioactifs, et que les crédits supplémentaires nécessaires à cette accélération soient libérés par le gouvernement du Canada.**

Afin de contrôler l'avancement des travaux dans ce domaine, le Comité ordonne à la Commission de contrôle de l'énergie atomique de comparaître devant lui au plus tard le 30 juin 1989 et de présenter, en audience publique, un programme révisé d'établissement d'une installation d'élimination ainsi qu'une description complète des paramètres qui serviront à juger de la pertinence du choix d'un site pour cette installation et à autoriser la conception et la construction de l'installation. Le Comité sait que l'Énergie atomique du Canada, Limitée a établi un tel programme par le passé, mais est d'avis que dorénavant l'établissement de ce programme doit être vu par l'organisme de réglementation. La CCÉA doit, bien sûr, consulter l'ÉACL afin de s'assurer que l'accélération du programme est techniquement réalisable. Il faut enfin laisser suffisamment de temps à la CCÉA pour qu'elle puisse mener l'étude globale sur la gestion des déchets nucléaires à long terme annoncée récemment par le Comité fédéral d'examen des évaluations environnementales. Le Comité est convaincu que la mise en oeuvre d'un programme vigoureux et hautement visible de gestion des déchets radioactifs est cruciale au maintien de la confiance du grand public à l'égard du programme nucléaire du Canada.

2. **Le Comité ordonne à la Commission de contrôle de l'énergie atomique de comparaître devant lui, en audience publique, au plus tard le 30 juin 1989 et de présenter un programme accéléré d'établissement d'une installation commerciale d'élimination des déchets radioactifs ainsi qu'une description de tous les paramètres dont la Commission se servira pour autoriser l'exploitation du site de l'installation. La Commission de contrôle de l'énergie atomique consultera l'ÉACL afin de s'assurer que l'accélération du programme est techniquement réalisable.**

Les problèmes techniques de la gestion des déchets radioactifs ne sont pas insurmontables. Le Comité est d'avis que ces déchets peuvent être manutentionnés, stockés, transportés et éliminés en toute sécurité, si on en a la volonté politique.

Les réacteurs de puissance du Canada ont fait l'objet de plusieurs études de sûreté, dont la plus récente fait partie de la Ontario Nuclear Safety Review dirigée par le Dr F. Kenneth Hare. Dans chacun des cas, on a jugé que les réacteurs présentaient une sûreté acceptable. Ainsi que l'écrit le Dr Hare, «les réacteurs d'Ontario Hydro sont exploités en toute sûreté avec une performance technique élevée... Le risque qu'il se produise un accident suffisamment grave pour être dangereux pour le public ne pourra jamais être nul, mais il est extrêmement négligeable» (Ontario, *Nuclear Safety Review*, 1988c, p. i-ii)

professionnels et techniques, l'inscription aux programmes d'enseignement du nucléaire continuant de décliner.

Tout en accordant son appui, de façon générale, au développement du nucléaire au Canada, le Comité admet qu'il existe des lacunes dans des volets précis de ce développement. Le présent rapport souligne certaines de ces lacunes et formule des recommandations permettant d'y remédier. Ces recommandations sont livrées dans la suite de la présente section.

Le Comité s'est particulièrement préoccupé du programme national de gestion des déchets radioactifs. L'électronucléaire produit en effet des substances extrêmement radioactives. Au Canada, ces déchets extrêmement radioactifs se présentent sous la forme de faisceaux combustibles d'uranium irradié, qui sont actuellement stockés dans chacune des centrales. Bien que le stockage du combustible épuisé dans des cuves de béton remplies d'eau soit une mesure suffisante pour un certain nombre de décennies, il faudra bien un jour l'éliminer de façon définitive. Il en irait de même pour les déchets de retraitement, si le Canada décidait de recycler le combustible irradié dans les nouveaux combustibles pour réacteur.

Le Comité est d'avis que l'élimination des déchets radioactifs par enfouissement en profondeur dans une formation géologique stable est une solution valable pour le Canada. Des travaux comparables sont en voie d'exécution dans d'autres pays, notamment en Suède où le programme d'élimination présente de nombreux parallèles avec celui du Canada, ce qui renforce la conviction du Comité. C'est la crainte du grand public à l'égard de la gestion des déchets radioactifs qui constitue peut-être la plus grande menace au programme nucléaire du Canada. Le report de la vérification définitive de la notion de l'enfouissement de plus d'une dizaine d'années, depuis le lancement en 1978 du programme mixte de gestion des déchets par le gouvernement fédéral et le gouvernement ontarien, n'a pas suffi à le rassurer.

Selon le Comité, il faut accélérer les travaux portant sur l'élimination des déchets radioactifs, responsabilité qui relève du gouvernement fédéral, non pas parce que les actuelles méthodes de stockage des déchets hautement radioactifs sont inadéquates ou dangereuses, mais bien afin de convaincre le grand public qu'on dispose d'une solution satisfaisante pour ce qui est de l'élimination à long terme de ces déchets. Tout particulièrement, il faut accélérer les phases de la vérification de la notion ainsi que de la sélection et de l'acquisition des sites, de sorte que le grand public sache au plus vite qu'on a trouvé le moyen et les lieux pour éliminer ces déchets. Le Comité admet que l'accélération du programme de gestion des déchets hautement radioactifs nécessite une augmentation des crédits à court terme. Il s'agit d'un modeste prix à payer pour mettre en oeuvre ce volet si critique du programme nucléaire du Canada.

L'ÉACL est la société fédérale de la Couronne ayant pour mission de promouvoir l'utilisation de l'énergie nucléaire. Cette société compte quatre divisions : 1) la Société de recherche, qui oeuvre dans le domaine de la recherche, du développement et de la démonstration (R, D et D); 2) la Société d'exploitation du CANDU, qui conçoit, construit et commercialise les réacteurs nucléaires CANDU et qui fournit des services d'ingénierie; 3) la Société radiochimique, qui produit des radionucléides à des fins médicales et industrielles, et qui fabrique également du matériel d'irradiation commercial et industriel; et 4) la Division des produits médicaux, qui produit du matériel de radiothérapie.

La CCÉA est l'organisme fédéral de réglementation qui contrôle le développement, l'application et l'utilisation de l'énergie atomique au Canada, depuis la production d'électricité dans des réacteurs de puissance à l'utilisation du cobalt 60 dans le traitement du cancer, en passant par la radiographie industrielle. La CCÉA participe également, pour le compte du gouvernement du Canada, à des mesures internationales de contrôle, qui comprennent des programmes de prévention de la prolifération des armements nucléaires par détournement de substances nucléaires.

Trois compagnies d'électricité provinciales exploitent aujourd'hui des réacteurs de puissance. Il s'agit d'Ontario Hydro, qui produit la moitié de son électricité grâce au nucléaire, d'Hydro-Québec et de la Commission d'énergie électrique du Nouveau-Brunswick. Bien qu'il soit exploité par trois compagnies d'électricité du centre et de l'est du Canada, l'électronucléaire est plus coûteux que la production d'électricité à partir de centrales au charbon ou de barrages hydro-électriques dans certaines conditions et dans certaines régions du pays. En Alberta par exemple, on peut produire de l'électricité dans des centrales au charbon situées à proximité de mines à ciel ouvert à un coût qu'il ne sera jamais possible d'atteindre au moyen de centrales nucléaires. Compte tenu du fait que la production d'électricité au charbon se fera dans certaines régions dans l'avenir prévisible, il est particulièrement important que certaines techniques de combustion du charbon, comme celles qui ont été décrites au Comité par la TransAlta Utilities, soient mises en oeuvre commercialement aussi rapidement que possible, afin de réduire au minimum les effets sur l'environnement.

Le Canada recèle d'importantes réserves d'uranium et les gisements de la Saskatchewan sont au nombre des plus riches du monde. L'uranium est extrait en Ontario et en Saskatchewan, et le Canada en exporte plus que tout autre pays. Le traitement de l'uranium et la fabrication du combustible pour réacteur se faisant aussi au pays, le Canada s'est doté de toutes les installations de traitement du combustible nucléaire nécessaires à l'exploitation du réacteur CANDU.

Malgré sa position dominante dans l'industrie nucléaire mondiale, l'industrie nucléaire canadienne n'a pas réussi à se garantir un afflux suffisant de travailleurs

Les effets sur l'environnement de la combustion de grandes quantités de combustibles fossiles, particulièrement du charbon, afin de produire de l'électricité sont alarmants. Les recherches montrent l'ampleur du risque posé à la santé publique, les coûts économiques fabuleux et la dégradation de l'environnement qui résultent de l'émission de gaz acides par des centrales alimentées en combustibles fossiles. Des chercheurs étudient activement les conséquences de l'accumulation de dioxyde de carbone dans l'atmosphère terrestre, effet inéluctable de la combustion de combustibles fossiles. Ils nous ont fait prendre conscience des risques manifestes de bouleversement climatique. En comparaison, le nucléaire constitue une technique menaçant peu l'environnement, du moins de l'avis du Comité.

Le nucléaire permet d'améliorer la sécurité des approvisionnements énergétiques du Canada, la plupart des éléments de notre programme nucléaire pouvant être réalisés au pays. De plus, une portion substantielle des travaux de recherche et de développement (R et D) menés au Canada relève de l'industrie nucléaire. Le Canada ne jouit pas de ressources scientifiques et techniques telles qu'il puisse se permettre de sacrifier le bassin des talents et les installations de R et D que supporte notre industrie nucléaire.

On compte presque 30 000 personnes dont l'emploi est relié directement à l'industrie du nucléaire au Canada. Cette industrie a mis au point, ici même, un réacteur dont le dossier d'exploitation continue d'être le meilleur de tous les réacteurs mis au point dans le monde. Le Canada est le chef de file en matière d'utilisation de radionucléides à des fins thérapeutiques; la radiothérapie a prolongé la vie de millions de personnes dans des pays de tous les coins du globe. Le Canada est également en tête de peloton dans le domaine de l'utilisation industrielle du rayonnement, qui s'étend à l'irradiation des aliments, au traitement des eaux usées et à la stérilisation des boues contenant des organismes pathogènes. Le programme nucléaire du Canada a donné naissance à des techniques qui sont utilisées dans des domaines non nucléaires, allant du dépistage des individus vulnérables au cancer à la conception de nouveaux joints d'étanchéité pour le lanceur de la navette spatiale américaine. Les normes d'assurance qualité et de contrôle de qualité que des fabricants canadiens ont dû élaborer à titre de fournisseurs du programme nucléaire ont été appliquées à d'autres gammes de produits et ont renforcé la position concurrentielle de sociétés canadiennes.

Le maintien de l'option nucléaire signifie qu'il faut préserver la vigueur de tous les secteurs de l'industrie : le secteur fédéral, que dirige l'Énergie atomique du Canada, Limitée (ÉACL) et la Commission de contrôle de l'énergie atomique (CCÉA), les compagnies d'électricité provinciales qui exploitent l'électronucléaire, le secteur privé qui s'occupe d'extraction minière, de minéralurgie et de fabrication, et enfin les universités et les collèges du Canada qui forment du personnel professionnel et qualifié.

raison de la dégradation de l'environnement que produit la combustion de quantités de plus en plus grandes de charbon dans les centrales thermiques de production d'électricité. Malheureusement, au Canada, ni le gouvernement fédéral ni l'industrie nucléaire n'ont su présenter cette option sous un jour bien favorable, et l'attitude du grand public est en conséquence ambivalente.

Dans son appui au développement du nucléaire, le Comité ne perd toutefois pas son sens critique. Le programme nucléaire du Canada présente en effet des imperfections et des problèmes sont inhérents à l'utilisation de l'énergie atomique. Ces imperfections et problèmes doivent toutefois être évalués à la lumière des conséquences des autres formes de développement énergétique, développement qui doit satisfaire divers besoins économiques, sociaux, environnementaux, stratégiques et techniques. Il est donc essentiel que ce soit un public bien informé qui prenne de telles décisions et qui fasse de tels compromis.

Ce n'est pas uniquement à ses défenseurs qu'il revient d'expliquer le nucléaire, ses opposants doivent en effet aussi se pencher sur des problèmes épineux. Le public et l'environnement sont-ils mieux protégés par la dispersion sans compter de grandes quantités de dioxyde de soufre, d'oxydes d'azote, de dioxyde de carbone et d'autres contaminants dans l'atmosphère, ou par l'enfouissement de quantités relativement petites de déchets radioactifs? Quelles sont les possibilités énergétiques à long terme de la société si elle décide de ne pas exploiter la fission nucléaire? Comment peut-on justifier l'abandon des immenses investissements consentis dans le nucléaire et d'où proviendront les ressources pour le remplacer par d'autres formes d'énergie? Et que l'Ontario substituera-t-elle à la moitié de son électricité qu'elle obtient de réacteurs nucléaires?

Le débat sur le nucléaire a emprunté des sentiers trop étroits au Canada. Il ne s'agit pas simplement de savoir s'il faut continuer de produire de l'électricité au moyen de réacteurs nucléaires. D'autres aspects doivent aussi être considérés : la rareté grandissante des autres solutions permettant de produire de l'électricité, les conséquences sur l'environnement de la non-utilisation de l'énergie atomique, la sécurité énergétique nationale, l'exploitation des compétences scientifiques et techniques acquises, les retombées technologiques et l'emploi de nombreux Canadiens.

À mesure que les réserves pétrolières et gazières classiques s'épuiseront et que les sites privilégiés de construction de centrales hydro-électriques seront exploités, l'énergie atomique s'imposera de plus en plus comme moyen de rechange pour produire de l'électricité. L'embargo pétrolier de 1973-1974 a instruit les Canadiens de l'Est des dangers d'une trop grande dépendance envers le pétrole importé pour des fins telles la production d'électricité. Dans certaines parties du Canada, l'électronucléaire est aujourd'hui économiquement alléchant, de même que dans de nombreux pays qui ne jouissent pas, comme le Canada, d'un éventail de ressources énergétiques.

SOMMAIRE ET RECOMMANDATIONS

Plus on avance vers la fin du XXe siècle, plus l'humanité s'approche de ce qu'un auteur a appelé un «tournant de son histoire». La croissance de la population du globe (on estime qu'elle a dépassé les cinq milliards en 1987), l'urbanisation massive et la poursuite d'un niveau de vie élevé exercent des pressions inégalées sur la planète. Les exemples de la dégradation de l'environnement sont si fréquents qu'on y réagit à peine. Quelles sont les priorités? Qu'arrivera-t-il si nous n'agissons pas? Quel est le coût des mesures de correction? Comment la société peut-elle mieux prévoir les répercussions sur l'environnement des diverses formes d'exploitation de ses ressources?

Le Comité estime que, dans certains cas, les aspects les plus inquiétants de la contamination de l'environnement sont liés à l'exploitation croissante par la société des ressources énergétiques de la planète. L'émission de gaz acides et de dioxyde de carbone dans l'atmosphère, par suite de la combustion de combustibles fossiles, est un excellent exemple de pollution qu'il est extrêmement difficile et coûteux de prévenir[1].

Les moyens que la société mettra en oeuvre d'ici la fin du siècle pour corriger ces problèmes influeront fondamentalement sur la qualité de vie de l'humanité au cours du prochain siècle. À cet égard, la question de l'énergie est un élément clé, l'énergie étant à la fois partie du problème et partie de la solution. Toute activité humaine dépend de la consommation d'énergie, sous une forme ou une autre. Toutefois, en contrepartie, toute exploitation de l'énergie par l'humanité pose un ensemble particulier de problèmes environnementaux.

Bien que la présente étude du développement du nucléaire au Canada porte essentiellement sur ses aspects techniques et économiques, le Comité n'a pas négligé les perspectives environnementales et sociales générales dans sa réflexion sur la contribution future du nucléaire, que ce soit au Canada ou à l'étranger.

Le Comité désire établir d'emblée une position très nette : **le maintien de l'option du nucléaire est vital aux intérêts du Canada,** autant qu'il l'est pour les intérêts de la société en général. Il est impératif de favoriser la poursuite du développement du nucléaire, en raison de l'insuffisance future des ressources pétrolières classiques et en

---

1. Par contamination de l'environnement, il faut entendre dans le présent rapport sa pollution par des contaminants artificiels, et non par des cycles géochimiques naturels susceptibles de produire les mêmes substances. Les éruptions volcaniques, par exemple, peuvent injecter du dioxyde de soufre dans l'atmosphère, tandis qu'on sait bien que le dioxyde de carbone est un élément naturel de l'air. Par contamination de l'environnement, il faut donc entendre sa perturbation par des produits de l'activité humaine émis en quantités telles que les cycles chimiques naturels sont modifiés, au point de menacer le bien-être de la race humaine.

Le Comité n'aurait pas pu mener à bien sa tâche sans les conseils de Dean Clay et Lawrence Harris de *Dean Clay Associates*, sans l'aide précieuse de son greffier, Eugene Morawski, et de Diane Gagnon-Beaupré, de Lucie S. Pilon et de Georges Royer, et sans le dévouement des traducteurs du Secrétariat d'État dont la tâche a été monumentale.

En raison de la nature technique du nucléaire et de la terminologie spécialisée qui a cours dans le domaine, une liste d'abréviations et de sigles est donnée à l'Annexe D, ainsi qu'un glossaire à l'Annexe E. L'étude renvoie à de nombreux ouvrages de référence, pour deux raisons. La première est que le nucléaire est complexe; la deuxième est que des sources étrangères d'information peu connues ont été utilisées dans sa réalisation.

succès technique, le programme nucléaire canadien continue d'être contesté de multiples façons. L'inquiétude du grand public quant à la sûreté des réacteurs et à la contamination de l'environnement a été d'abord éveillée par l'incident de la centrale Three Mile Island, survenu aux États-Unis en 1979, puis avivée par l'accident de Tchernobyl, survenu en Union soviétique en 1986. On soulève régulièrement des questions quant à la viabilité économique de l'électronucléaire. Le Comité permanent de l'énergie, des mines et des ressources s'est donc donné le mandat qui suit, conformément à l'article 96(2) du Règlement :

> **Réaliser une étude portant sur les aspects économiques de l'énergie nucléaire au Canada et sur toute autre question qui s'y rattache.**

L'étude a commencé en novembre 1987, par des audiences publiques tenues à Ottawa. Le Comité s'est rapidement rendu compte qu'il ne lui suffirait pas d'entendre des témoins pour formuler des recommandations dans un domaine aussi complexe que le nucléaire. En conséquence, il a visité diverses installations nucléaires du Canada et s'est déplacé aux États-Unis, en Suède, en Allemagne de l'Ouest et en France afin de pouvoir examiner de près les programmes nucléaires de ces pays. C'est grâce à la coopération offerte pendant ces déplacements que le Comité a pu recueillir les renseignements dont il avait besoin et se former les opinions qu'il livre dans le présent rapport.

Le Comité s'est attardé dans son étude aux aspects techniques et économiques du développement du nucléaire au Canada, incluant le programme de l'électronucléaire, la production de radionucléides à des fins médicales et industrielles, ainsi que le développement de certaines technologies connexes. Puisque ces divers aspects sont tous liés les uns aux autres, le Comité a décidé qu'ils devaient être étudiés comme s'il s'agissait de manifestations du même problème. D'autres comités de la Chambre des communes ayant comme mandat de veiller à l'étude de l'environnement et de la santé publique, ces éléments de la problématique nucléaire ne sont pas traités en détail dans le présent rapport.

Le Comité propose 14 recommandations. Celles-ci sont présentées dans la section intitulée Sommaire et Recommandations qui suit l'Avant-propos. Des déclarations de dissension de deux membres du Comité sont présentées à l'Annexe A.

De nombreuses personnes et organisations ont aidé le Comité dans ses travaux, tant au Canada que dans les quatre pays visités. À tous ceux qui sans compter leur temps ont partagé leurs opinions avec lui et son personnel, le Comité exprime ses vifs remerciements. La liste des témoins qui ont été entendus est donnée à l'Annexe B; celle des personnes qui ont aidé le Comité pendant ses déplacements est donnée à l'Annexe C. Le Comité tient aussi à remercier le ministère des Affaires extérieures qui, à bref avis, a su organiser remarquablement ses déplacements à l'étranger.

AVANT-PROPOS

En septembre 1987, le Comité a déposé un rapport intitulé *Le pétrole — Rareté ou sécurité?* (Canada, Chambre des communes, Comité permanent de l'énergie, des mines et des ressources, 1987), dans lequel il présentait les résultats d'une étude d'un an portant sur l'offre future de brut léger classique au Canada. Il y constatait que la production canadienne de pétrole léger classique allait chuter substantiellement, et que ce déclin serait compensé soit par une augmentation de l'importation de brut léger, soit par de coûteux investissements dans des installations d'extraction et d'amélioration qui sont nécessaires à l'exploitation des grandes ressources canadiennes de bitume contenues dans les sables pétrolifères de l'Alberta. Par contre, la mise en valeur des gisements pétroliers canadiens non classiques ne pourra, a estimé le Comité, que compenser partiellement le déclin de la production de brut léger de l'Ouest canadien.

L'étude a fait la lumière sur l'insuffisance croissante de la production de brut américain comparativement à la consommation nationale, insuffisance qui soulève de vives inquiétudes quant à la sécurité nationale des États-Unis. Le rapport a également porté sur la répartition mondiale des ressources pétrolières récupérables. Il y était constaté que les hydrocarbures légers (brut léger et gaz naturel) dont la production est facile et peu coûteuse sont concentrés dans l'hémisphère oriental (le brut dans le golfe Persique et le gaz naturel en Union soviétique), tandis que les ressources en hydrocarbures lourds dont la production est difficile et l'amélioration coûteuse (le brut lourd, le bitume et l'huile de schiste) se retrouvent surtout dans l'hémisphère occidental (pétrole lourd au Venezuela, bitume au Canada et huile de schiste aux États-Unis). Les pays de l'OPEP détiennent la presque totalité de l'actuel excédent mondial de production, qui se situe à 10 millions de barils par jour, les deux tiers de cet excédent étant le fait des producteurs du golfe Persique. La principale constatation de l'étude était que tous les éléments propices à une autre perturbation encore plus profonde de l'offre internationale de pétrole brut léger étaient en place.

Au vu de cette constatation et compte tenu des inquiétudes grandissantes que soulèvent les effets de l'utilisation des combustibles fossiles sur l'environnement, le Comité a décidé d'étudier un volet du système énergétique canadien qui est largement débattu dans le public, mais que le Parlement n'a pas étudié dans son ensemble. Les membres du Comité ont donc jugé légitime de mener une étude rétrospective et prospective du développement de l'énergie nucléaire au Canada. Le présent rapport livre les résultats de cette étude.

Au cours des 45 dernières années, le Canada a mis à profit les réalisations scientifiques et techniques de la réaction nucléaire en chaîne pour se doter d'un réacteur unique présentant le meilleur dossier d'exploitation au monde. Malgré ce

TABLE DES MATIÈRES

DÉMYSTIFICATION

DE L'ÉNERGIE NUCLÉAIRE

Le Comité permanent de l'énergie, des mines et des ressources a l'honneur de présenter son

DIXIÈME RAPPORT

Conformément à l'article 96(2) du Règlement, le Comité permanent de l'énergie, des mines et des ressources a mené une étude sur les aspects économiques du nucléaire au Canada. Après audition des témoins, le Comité a décidé de présenter le rapport qui suit à la Chambre.

Membres du Comité permanent de l'énergie, des mines et des ressources

Présidente : **Barbara Sparrow, députée** — Calgary-Sud

Vice-président : **Aurèle Gervais, député** — Timmins—Chapleau

Paul Gagnon, député — Calgary-Nord
Len Gustafson, député — Assiniboia
Russel MacLellan, député — Cape Breton—The Sydneys
Lorne Nystrom, député — Yorkton—Melville
Bob Porter, député — Medicine Hat

Greffier du comité

Eugene Morawski

Conseillers du comité

Dean N. Clay

Lawrence Harris

Deuxième session de la trente-troisième législature

CHAMBRE DES COMMUNES

Fascicule nº 48

Le mardi 21 juin 1988
Le mercredi 22 juin 1988

Présidente: Barbara Sparrow

Procès-verbaux et témoignages du Comité permanent

De l'Énergie, des Mines et des Ressources

CONCERNANT:

Considération de l'ébauche d'un rapport

Deuxième session de la
trente-troisième législature, 1986-1987-1988

HOUSE OF COMMONS

Issue No. 48

Tuesday, June 21, 1988
Wednesday, June 22, 1988

Chairman: Barbara Sparrow

Minutes of Proceedings and Evidence of the Standing Committee on

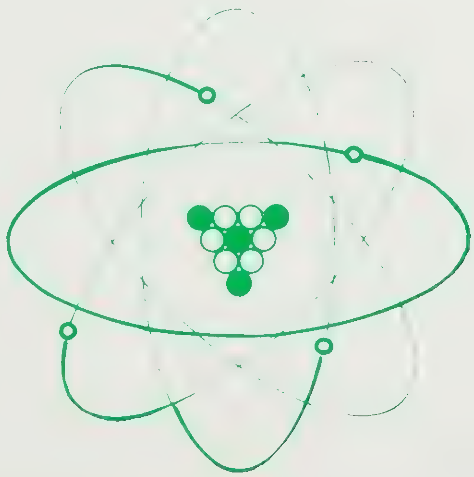
Energy, Mines and Resources

RESPECTING:

Consideration of a draft report

Second Session of the
Thirty-third Parliament, 1986-87-88

DÉMYSTIFICATION DE L'ÉNERGIE NUCLÉAIRE



Barbara Sparrow, députée

Dixième rapport du

HOUSE OF COMMONS

Issue No. 49

Tuesday, September 20, 1988

Chairman: Barbara Sparrow

Minutes of Proceedings and Evidence of the Standing Committee on

Energy, Mines and Resources

RESPECTING:

Pursuant to Standing Order 96(2), consideration of the Report on the Energy Options Process

APPEARING:

The Honourable Marcel Masse, Minister of Energy, Mines and Resources

WITNESS:

(See back cover)

Second Session of the Thirty-third Parliament, 1986-87-88

CHAMBRE DES COMMUNES

Fascicule nº 49

Le mardi 20 septembre 1988

Présidente: Barbara Sparrow

Procès-verbaux et témoignages du Comité permanent de

L'énergie, des mines et des ressources

CONCERNANT:

Conformément à l'article 96(2) du Règlement, examen du Rapport de la confluence énergétique

COMPARAÎT:

L'honorable Marcel Masse, ministre de l'Énergie, des Mines et des Ressources

TÉMOIN:

(Voir à l'endos)

Deuxième session de la trente-troisième législature, 1986-1987-1988

23880

STANDING COMMITTEE ON ENERGY, MINES AND RESOURCES

Chairman: Barbara Sparrow

Vice-Chairman: Aurèle Gervais

Members

Paul Gagnon
Len Gustafson
Russell MacLellan
Lorne Nystrom
Bob Porter—(7)

(Quorum 4)

Eugene Morawski
Clerk of the Committee

COMITÉ PERMANENT DE L'ÉNERGIE, DES MINES ET DES RESSOURCES

Présidente: Barbara Sparrow

Vice-président: Aurèle Gervais

Membres

Paul Gagnon
Len Gustafson
Russell MacLellan
Lorne Nystrom
Bob Porter—(7)

(Quorum 4)

Le greffier du Comité
Eugene Morawski

Published under authority of the Speaker of the House of Commons by the Queen's Printer for Canada

Available from the Canadian Government Publishing Center, Supply and Services Canada, Ottawa, Canada K1A 0S9

Publié en conformité de l'autorité du Président de la Chambre des communes par l'Imprimeur de la Reine pour le Canada

En vente: Centre d'édition du gouvernement du Canada, Approvisionnements et Services Canada, Ottawa, Canada K1A 0S9

MINUTES OF PROCEEDINGS

TUESDAY, SEPTEMBER 20, 1988
(77)

[*Text*]

The Standing Committee on Energy, Mines and Resources met at 3:33 o'clock p.m., in Room 371, West Block, this day, the Chairman, Barbara Sparrow, presiding.

Members of the Committee present: Paul Gagnon, Len Gustafson, Russell MacLellan, Lorne Nystrom and Barbara Sparrow.

In attendance: Dean Clay, Consultant.

Appearing: The Honourable Marcel Masse, Minister of Energy, Mines and Resources.

Witness: *From the Department of Energy, Mines and Resources*: George Anderson, Assistant Deputy Minister, Energy Policy Sector.

In accordance with its mandate under Standing Order 96(2), the Committee commenced consideration of the Report on the Energy Options Process.

The Minister made an opening statement and, with the witness, answered questions.

At 4:40 o'clock p.m., the Committee proceeded to an *in camera* meeting.

At 4:45 o'clock p.m., the Committee adjourned to the call of the Chair.

Eugene Morawski
Clerk of the Committee

PROCÈS-VERBAL

LE MARDI 20 SEPTEMBRE 1988
(77)

[*Traduction*]

Le Comité permanent de l'énergie, des mines et des ressources se réunit aujourd'hui à 15 h 33, dans la pièce 371 de l'édifice de l'Ouest, sous la présidence de Barbara Sparrow, (*présidente*).

Membres du Comité présents: Paul Gagnon, Len Gustafson, Russell MacLellan, Lorne Nystrom et Barbara Sparrow.

Aussi présent: Dean Clay, conseiller.

Comparaît: L'honorable Marcel Masse, ministre de l'Énergie, des Mines et des Ressources.

Témoin: *Du ministère de l'Énergie, des Mines et des Ressources*: George Anderson, sous-ministre adjoint, secteur de la politique énergétique.

Conformément au mandat que lui confie le paragraphe 96(2) du Règlement, le Comité entreprend l'étude du rapport sur la confluence énergétique.

Le Ministre fait une déclaration préliminaire, puis lui-même et le témoin répondent aux questions.

À 16 h 40, le Comité adopte le huis clos.

À 16 h 45, le Comité s'ajourne jusqu'à nouvelle convocation de la présidente.

Le greffier du Comité
Eugene Morawski

EVIDENCE

[*Recorded by Electronic Apparatus*]

[*Texte*]

Tuesday, September 20, 1988

• 1532

The Chairman: I would like to call this meeting of the Standing Committee on Energy, Mines and Resources to order. We have a quorum to hear witnesses. The agenda has been circulated. The order of the day, pursuant to Standing Order 96.(2), is consideration of the report on the energy options process. On August 18 I received from Minister Marcel Masse a letter which referred the *Energy Options* report to this committee for consideration.

We have with us today the minister, who will make some general comments with regard to the report on energy options. After the conclusion of his remarks, I would ask committee members to stay behind so we could discuss our approach—how we are going to review this study and what our agenda will be for the next couple of weeks. Mr. Masse has a commitment later on and will be with us until about 4.30 p.m.

So if you would begin with your opening address, Mr. Minister, we would have time for a few questions. Hopefully we can keep them general today. And I would hope we could invite you back at a later date if we needed more information. Mr. Minister.

L'honorable Marcel Masse (ministre de l'Énergie, des Mines et des Ressources): *Thank you.*

Madame la présidente, honorables députés.

Je vous remercie, madame la présidente, de me fournir l'occasion de comparaître devant ce Comité pour présenter *Confluence énergétique*, le premier dialogue public d'importance sur la politique énergétique canadienne qui se soit tenu au pays en trois décennies.

En maintes occasions dans le passé, votre Comité m'a transmis des rapports et des conseils sur toute une gamme de questions-clés en ce qui a trait à la politique énergétique. Je suis heureux de faire de nouveau appel à votre expérience, cette fois-ci pour examiner le rapport de *Confluence énergétique*.

J'insisterai d'abord, madame la présidente, sur l'importance du secteur énergétique pour le bien-être des Canadiens. Notre pays a été doté de ressources énergétiques abondantes et diversifiées. Trois cent mille personnes travaillent dans le secteur énergétique, lequel apporte une contribution de 6 p. 100 à notre produit national brut (PNB). De plus, ce secteur bénéficie de 14 p. 100 des investissements effectués au Canada et génère 11 p. 100 de nos revenus d'exportation. Il est indubitable que les tendances dans la mise en valeur et l'utilisation de l'énergie ont des répercussions directes sur l'avenir économique des Canadiens.

TÉMOIGNAGES

[*Enregistrement électronique*]

[*Traduction*]

Le mardi 20 septembre 1988

La présidente: La séance du Comité permanent de l'Énergie, des Mines et des Ressources est ouverte. Nous avons le quorum pour entendre les témoins. L'ordre du jour vous a été distribué. Conformément à l'article 96.(2) du Règlement, notre tâche est d'étudier le rapport de *Confluence énergétique*. Le 18 août j'ai reçu du ministre, M. Marcel Masse, mentionnant le renvoi pour étude à votre comité de ce rapport de *Confluence énergétique*.

Nous accueillons aujourd'hui le ministre, qui fera quelques commentaires de caractère général sur ce rapport. Quant il aura terminé, je demanderais aux membres du Comité de rester pour discuter stratégie: comment aborder ce rapport, quel calendrier prévoir pour les deux prochaines semaines. M. Masse a un rendez-vous et ne pourra rester avec nous que jusqu'à 16h30.

Si vous voulez bien commencer maintenant votre déclaration, monsieur le ministre, il nous restera un peu de temps pour poser quelques questions. Il serait souhaitable qu'elle reste générale aujourd'hui. J'espère que nous pourrons vous inviter à revenir plus tard si nous avons besoin d'un complément d'information. Monsieur le ministre.

Hon. Marcel Masse (Minister of Energy, Mines and Resources): *Merci*

Madam Chairman, members of Parliament.

I would like to thank you, Madam Chairman for the opportunity to appear before this committee to speak about *Energy Options*, the first major public dialogue on the Canadian energy policy in three decades.

On a number of occasions in the past, your committee has provided me with reports and advice on a variety of key energy policy issues. It is therefore with great pleasure that I ask again for your contribution, this time to examine the *Energy Options* report.

I will briefly insist on the importance of the energy sector for the well-being of Canadians. Our country is blessed with abundant and diversified energy resources. The energy sector employs 300,000 people and generates 6% of our gross domestic product (GDP). Further, it accounts for 14% of Canada's investment and 11% of our export revenues. Without doubt, trends in the development and use of energy have a direct bearing on the economic future of Canadians.

[*Texte*]

• 1535

Formuler un cadre de politique qui nous permettra de maximiser les avantages que nous retirons de notre capital-ressources en ce domaine est le défi qu'il nous faut relever.

La politique énergétique doit être suffisamment souple pour s'adapter à un monde en perpétuelle mutation. Elle doit aussi refléter les préoccupations et les aspirations des Canadiens. Madame la présidente, on ne peut élaborer une telle politique en vase clos. Il nous faut plutôt être prêts à consulter les provinces, l'industrie de l'énergie et les autres parties intéressées, sur toute question d'intérêt mutuel. Une étroite collaboration s'avère donc essentielle.

D'abord et avant tout, il faut que les différents gouvernements collaborent. En vertu de la Constitution canadienne, les ressources naturelles appartiennent aux provinces. Il s'agit là de l'une des plus importantes prérogatives de chacune des provinces dans la Confédération canadienne. Il faut donc que les gouvernements provinciaux jouent le rôle de gestionnaires efficaces afin de s'assurer que ces ressources soient exploitées de façon à ce que leurs citoyens en retirent le maximum d'avantages économiques. Ils doivent aussi adopter une attitude d'intendants économes et veiller à ce que l'on respecte les normes en matière d'économie d'énergie et de protection de l'environnement.

Le gouvernement canadien a aussi ses prérogatives dans le domaine de la politique énergétique: elles découlent de sa compétence constitutionnelle en matière de commerce interprovincial et international, de fiscalité et de rôle de gardien de la paix, de l'ordre et de la bonne administration publique. Ces responsabilités sont à maints égards moins précises que celles des provinces. Voilà pourquoi la mise en oeuvre efficace des politiques énergétiques du Canada exige que l'on reconnaisse l'existence de responsabilités partagées entre le gouvernement canadien et les gouvernements provinciaux.

En raison de ce partage des pouvoirs, il devient difficile et habituellement imprudent pour le gouvernement canadien d'élaborer une politique en ce domaine d'une façon unilatérale. Les provinces ont le pouvoir d'entraver la mise en oeuvre des politiques énergétiques nationales avec lesquelles elles ne sont pas d'accord et de favoriser le succès de celles qui leur conviennent. Il est donc impératif d'élaborer une politique énergétique fondée sur le dialogue et la collaboration avec les provinces.

Les Canadiens ont rarement eu, au cours de leur histoire, l'occasion de participer à un débat public sur l'orientation générale de la politique énergétique. De fait, ils n'avaient pas bénéficié de cette occasion depuis 30 ans, soit depuis les audiences de la Commission royale sur l'énergie en 1958 (La Commission Borden).

Et pourtant, au cours des 30 dernières années, de profonds changements sont survenus dans le secteur de l'énergie sur le plan économique. Certains de ces changements ont été provoqués par des événements

[*Traduction*]

The challenge we face is to formulate a policy framework which will maximize the benefits of our resource potential.

Energy policy must be sufficiently flexible to adjust to a constantly changing world. It should also reflect the concerns and aspirations of Canadians. Such a policy, Madam Chairman, cannot be developed in isolation. Rather, it requires a willingness to consult with the provinces, the energy industry and other interested parties on any energy issues of mutual importance. It also requires close co-operation.

First of all, there must be co-operation among governments. Under the Canadian Constitution, the provinces own the resources. This is one of the most important prerogatives of a province in our confederation. It requires the provincial governments to act as effective managers of the resources, ensuring that they are exploited in a manner that maximizes economic benefit to their citizens. It also obliges them to be prudent stewards, to ensure that conservation and environmental values are observed.

The energy policy prerogatives of the Government of Canada derive from its constitutional jurisdiction over interprovincial and international trade, over taxation, and in support of its role in maintaining peace, order and good public administration. These responsibilities are in many ways more diffuse than those of the provinces. Because of this, the effective management of Canada's energy policies requires recognition of shared responsibilities between the federal and provincial governments.

These shared powers make it difficult, and usually unwise, for the Canadian government to make policy unilaterally. Provinces have the power to frustrate federal energy policies with which they disagree, and to ensure success for the policies that they support. This makes it essential that energy policy be developed in the context of dialogue and co-operation with the provinces.

In the course of our history, Canadians have rarely been provided the opportunity to participate in a public debate on the broad orientation of energy policy. In fact, they did not have such an occasion in the past 30 years, that is, since the hearings of the Royal Commission on Energy in 1958 (the Borden Commission).

During the past 30 years, however, Canada's energy economy has undergone significant changes. Some of these have resulted from major international events, others from domestic policy decisions. For example, the

[*Text*]

importants sur la scène internationale et d'autres ont été le résultat de décisions politiques canadiennes. Par exemple, l'émergence de l'OPEP comme force politique et économique majeure dans les années 1970 a entraîné une escalade des prix mondiaux de pétrole qui a forcé le système énergétique international à modifier considérablement sa structure. Les changements subséquents dans les conditions du marché, la perte de pouvoir de l'OPEP et le déclin des prix du pétrole ont fait naître une période de transition à laquelle l'industrie du pétrole continue de s'adapter.

Les décisions politiques sur le plan intérieur ont également contribué à faire évoluer le secteur énergétique. Depuis 1984, notre gouvernement a modifié fondamentalement la politique énergétique et a dû faire face à plusieurs défis. Nous avons complètement démantelé le Programme énergétique national et, de ce fait, nous avons mis fin à des années d'acrimonie entre le gouvernement du Canada et ceux des provinces. Nous avons aidé l'industrie du pétrole à s'adapter à la situation créée par l'effondrement des prix du pétrole en 1986. Nous avons procédé à une déréglementation systématique des industries de l'énergie, les laissant libres de profiter des occasions qui se présentaient sur le marché concurrentiel et nous avons ramené la certitude et la stabilité nécessaires pour promouvoir les investissements et créer des emplois. Et tout cela, nous l'avons accompli en veillant rigoureusement à la protection de l'environnement.

• 1540

Peu après ma nomination au poste de ministre de l'Énergie, des Mines et des Ressources, en juin 1986, j'ai acquis la conviction que ces changements fondamentaux marquaient un point tournant. J'ai eu la nette impression que les Canadiens devaient faire une pause, effectuer un inventaire et réfléchir sur les défis et que nous devons tous relever en matière de politique énergétique dans l'avenir.

Voilà pourquoi, madame la présidente, j'ai annoncé le 13 avril 1987 le lancement du processus appelé: *Confluence énergétique*: *un dialogue pancanadien*. Je m'étais fixé des objectifs ambitieux. Je voulais que l'on effectue une révision globale de toutes les questions liées à l'énergie et une évaluation des choix et des perspectives qui s'offrent aux Canadiens au seuil du XXIe siècle. Je n'étais pas uniquement intéressé à obtenir un volumineux rapport préparé par un groupe d'experts. Je voulais aussi fournir à tous les Canadiens l'occasion de participer à un débat public sur le secteur énergétique qui a une nette incidence sur la qualité de nos vies.

Je croyais à ce moment-là, et je continue à croire, que la politique énergétique doit être fondée sur un dialogue constructif, auquel doivent participer non seulement les gouvernements et l'industrie, mais aussi les citoyens canadiens. Je voulais favoriser le plus d'échanges de vues possible.

[*Translation*]

emergence of OPEC as a major political and economic force in the 1970s led to an escalation of world oil prices that has stimulated major changes in the structure of the international energy system. The subsequent change in market circumstances, loss of OPEC power, and decline in oil prices has wrought a transition to which the energy industry is still adjusting.

Domestic policy decisions have also contributed to the evolution of the energy sector. Since 1984, our government has fundamentally changed energy policy and responded to several challenges. We have systematically dismantled the National Energy Program, thereby ending years of acrimony between the federal and provincial governments. We have facilitated the petroleum industry's adjustment to the collapse of oil prices in 1986. We have systematically deregulated the energy industries, leaving them free to respond to opportunities in competitive markets, and we have provided the certainty and stability needed to promote job-creating investments. We have done this within a framework of strong protection for the environment.

Shortly after I was appointed Minister of Energy, Mines and Resources in June, 1986, I became convinced that these fundamental changes marked a turning point. I felt that it was necessary for Canadians to pause, to take stock, to reflect on the energy policy challenges that we will face in future.

Madam Chairman, this is why, on April 13, 1987 I announced the process called: *Energy Options*: *A Canadian Dialogue*. My goals were ambitious. I wanted to see a comprehensive review of energy issues and an assessment of Canada's options and perspectives on the eve of the 21st century. However, I was not solely interested in a voluminous report produced by a group of experts. I also wanted to provide all Canadians with the opportunity to participate in the public debate in this area which clearly affects the quality of our lives.

I believed, and I still believe, that energy policy should be based on a constructive dialogue, involving not only governments and the industry, but also Canadian citizens. I wanted to encourage the broadest possible exchange of views.

[*Texte*]

Pour diriger le processus, j'ai nommé M. Thomas E. Kierans, président de MacLeod Young Weir Ltd., à la présidence d'un comité consultatif de 23 membres représentant les différentes régions et les divers secteurs économiques du Canada.

Le Comité consultatif a accompli une tâche gigantesque. En vue de stimuler le débat et d'obtenir l'opinion des Canadiens, il a tenu durant un an une série de conférences et de colloques auxquels ont pris part environ 700 personnes. Il a aussi donné à contrat la préparation de documents passant en revue les recherches qui s'effectuaient alors; il a distribué deux publications pour stimuler la discussion; il a invité le public à faire connaître son opinion. Plus de 600 personnes ont répondu à l'appel et ont fait connaître leur point de vue. Le Comité consultatif a publié un rapport qui par sa largeur de vue et la profondeur de son analyse influencera l'orientation des politiques énergétiques qui seront formulées au Canada pendant les années à venir.

J'aimerais profiter de l'occasion, madame la présidente, pour remercier publiquement les membres du Comité consultatif de la diligence avec laquelle ils se sont acquittés de leur tâche. C'est grâce à leur travail ardu et à leur perspicacité que *Confluence énergétique* s'est avérée un succès. Je voudrais également exprimer ma profonde gratitude à l'endroit de tous ceux et celles qui ont participé au processus de *Confluence énergétique*.

Le rapport rédigé par le Comité consultatif contient une mine de renseignements d'un prix inestimable sur les choix qui s'offriront à nous dans l'avenir ainsi que certaines idées intéressantes et stimulantes concernant l'approche que les gouvernements et l'industrie devraient adopter à l'égard de ces options. Comme je l'ai fait remarquer plus tôt, la politique énergétique était une source de division et de querelles lorsque notre gouvernement a été porté au pouvoir. Notre gouvernement s'est appliqué à en faire une source d'unité et de bonne entente. Après avoir lu ce rapport, je peux affirmer que nos efforts ont été couronnés de succès. Les messages importants du rapport sont compatibles avec les orientations que nous avons adoptées en formulant notre politique énergétique. Lorsqu'il y a des écarts, les ajustements que propose le rapport sont généralement d'une importance marginale.

Le rapport recommande sept principes pour guider l'élaboration de la politique énergétique, notamment:

—mettre en valeur les ressources énergétiques afin de favoriser la croissance économique et la prospérité;

—assurer la sécurité énergétique grâce à la diversification et à l'adaptation au changement plutôt qu'en accumulant nos ressources et en essayant d'être autosuffisant à des coûts élevés;

—veiller à ce que les objectifs environnementaux ne soient pas subordonnés aux objectifs énergétiques ou à d'autres considérations économiques;

[*Traduction*]

To spearhead the process, I appointed Mr. Thomas E. Kierans, President of MacLeod Young Weir Ltd., to act as Chairman of the 23-member advisory committee representing Canada's different regional economic sectors.

The advisory committee accomplished a major task. In order to encourage debate and elicit the opinions of Canadians, the committee held a series of conferences and seminars over a one-year span in which some 700 people participated. It also commissioned papers reviewing current research; issued two publications to stimulate discussions; and invited responses from the public, of which over 600 were received. The advisory committee produced a report which had the bredth and vision of analysis to influence the direction of energy policy formulation in Canada for years to come.

I would like to take this opportunity, Madam Chairman, to thank publicly the members of the advisory committee for the diligence with which they carried out their task. Their hard work and insight have done much to ensure the success of *Energy Options*. I also would like to express my gratitude to all the participants in the *Energy Options* process.

The report produced by the advisory committee contained much valuable information about the choices we will face in the future, as well as some interesting and provocative ideas regarding the approach that governments and industry should take in making these choices. As I noted earlier, when this government took office, energy policy was viewed as a source of division and contention in Canada. The government set out to make it a source of unity and common understanding. Reading this report, I would say that we have been successful. The central messages of the report are consistent with the directions we have already set for energy policy. Where there are differences, the adjustments called for by the report are generally marginal.

The report recommends a framework of seven broad principles to guide energy policy formulation, including:

—developing energy resources to provide economic growth and prosperity;

—achieving energy security through diversifying and adapting to change rather than by hoarding and pursuing self-sufficiency at any cost;

—ensuring that environmental goals are not subordinated to social or economic objectives;

[*Text*]

—confirmer le rôle du mécanisme du marché comme moyen de répartir les ressources avec efficacité et efficience;

—percevoir et dépenser les recettes par le biais d'un régime fiscal qui soit non discriminatoire, stable, prévisible et neutre, de façon à favoriser l'harmonie entre les gouvernements;

—faire valoir l'importance de l'efficacité énergétique en matière de compétitivité économique et de respect de l'environnement;

—reconnaître le rôle de la technologie dans l'accroissement des choix énergétiques et de la qualité de l'environnement.

• 1545

Le Comité consultatif a fait plusieurs recommandations spécifiques découlant de ces principes et de l'examen qu'il a effectué des questions relatives au développement économique, à la sécurité énergétique, à l'environnement, aux marchés de l'énergie, au système fiscal, au rendement énergétique et à la technologie. Nous ne disposons pas assez de temps aujourd'hui pour examiner en détail chacune de ces recommandations. Je tiens, cependant, à commenter certaines d'entre elles qui ont suscité des critiques de la part du public.

Dans son chapitre sur la sécurité énergétique, le rapport de *Confluence énergétique* mentionne qu'on ne devrait pas subventionner les mégaprojets ou toute autre forme de remplacement de l'offre et de la demande d'énergie pour des raisons de sécurité. Cela a amené certains commentateurs à remettre en question les investissements et l'aide que le gouvernement a consenti à fournir aux promoteurs des projets Hibernia et Husky.

Cette critique est totalement injustifiée. Notre stratégie pour les mégaprojets va dans le même sens que le rapport de *Confluence énergétique* qui reconnaît que ceux-ci peuvent comporter des mesures d'encouragement pour des raisons telles que la création d'emplois et les retombées industrielles régionales, et presse les gouvernements de le dire explicitement. C'est ce que nous avons fait. Nous avons reconnu que ces projets offrent d'importantes retombées économiques en matière de développement, tant pour les collectivités où ils sont situés que pour le Canada tout entier. Ainsi, en accroissant les aprovisionnements énergétiques du Canada, ils contribuent à assurer notre sécurité énergétique. Cette approche concorde avec celle que publiait mon Ministère en août 1987. Tous les projets, enfin, que nous avons encouragés l'ont été selon le cadre de notre politique d'aide pour les mégaprojets de juin 1987.

Il y a eu certaines critiques du rapport de *Confluence énergétique* au sujet de ses recommandations sur les principes à suivre pour en arriver à établir un meilleur marché pour le gaz naturel. À mon avis, les auteurs du rapport se sont efforcés de maintenir un certain équilibre concernant l'une des questions les plus complexes de la

[*Translation*]

—relying on market mechanisms wherever possible to achieve efficient allocation of energy resources;

—raising and spending revenues through the fiscal system in ways that are non-discriminatory, stable, predictable and neutral, and which foster harmony among governments;

—the importance of energy efficiency to economic competitiveness and environmental sustainability;

—the role of energy technology in enhancing Canada's energy choices and environmental quality.

The advisory committee made several specific recommendations that derive from these principles and from their examination of the issues of economic development, energy security, the environment, energy markets, the fiscal system, energy efficiency and technology. We do not have time today to review those recommendations in detail. I would, however, like to comment on some recommendations that have given rise to critical public comment.

In its chapter on energy security, the *Energy Options* report comments that there should be no need to subsidize megaprojects or any other energy supply or demand alternatives for security reasons. This has led some commentators to question the investments and assistance that the Government of Canada has agreed to provide to the sponsors of the Hibernia and Husky projects.

This criticism is totally unjustified. Our approach to megaprojects is fully consistent with the *Energy Options* report, which acknowledged that incentives might be provided to megaprojects for reasons such as employment creation and regional industrial benefits, and urged governments to state this explicitly. We have done so. We have recognized that these projects offer significant economic development benefits, both to the regions in which they are located and to Canada as a whole. As well, by enhancing Canada's domestic energy supplies, they contribute to Canada's energy security. This approach is also consistent with my department's August, 1987 discussion paper on energy security. Finally, all of the projects we have assisted have been helped in accordance with our megaproject assistance policy of June, 1987.

There has been some criticism directed at the *Energy Options* report for its recommendations regarding the principle that should be followed in moving towards a more effective natural gas market. In my view, the authors of the report endeavoured to steer a balanced course through one of the most complex of energy policy issues.

[*Texte*]

politique énergétique. En étudiant les recommandations du Comité consultatif, nous ne devrions pas oublier que la déréglementation du gaz naturel a été un processus très ardu mais qu'elle a quand même été un succès. L'industrie et les gouvernements ont généralement accepté de bon gré la période de transition qui a mené à un marché fonctionnant librement, où les acheteurs et les fournisseurs sont les seuls à fixer les prix et à établir les autres conditions au contrat. Nous devrions noter ce qu'on a réalisé jusqu'à maintenant:

—nous nous sommes rapprochés de l'objectif de l'accès libre et non discriminatoire aux marchés, aux modes de transport et aux systèmes de distribution;

—les distributeurs négocient de nouveau des approvisionnements à long terme, choisissant la méthode du portefeuille pour faire face à leurs obligations en ce qui concerne les services;

—le gouvernement a en général rendu possible une transition ordonnée vers un marché qui fonctionne bien.

J'ai confiance que d'autres progrès seront accomplis avec le temps.

Un grand nombre de groupes canadiens ont appuyé fortement les recommandations du rapport de *Confluence énergétique* concernant l'efficacité énergétique. J'ai été personnellement très heureux de constater que le Comité consultatif a insisté sur l'importance des lois du marché. Selon le Comité, c'est encore le moyen le plus rentable d'en arriver à l'efficacité économique en matière d'énergie. Il a par ailleurs recommandé au gouvernement d'accorder son appui aux innovations technologiques et à leur mise au point en vue d'améliorer davantage cette efficience.

Le 9 septembre, j'ai annoncé que le gouvernement consacrerait plus de 600 millions de dollars, d'ici 1993, pour promouvoir la recherche et le développement dans le secteur énergétique et une large gamme d'activités visant à favoriser l'efficacité et la diversification énergétiques. En plus d'encourager la poursuite de la prospection de combustibles classifiques et non-classiques, j'ai demandé en particulier que l'on affecte plus de ressources à l'efficacité énergétique, aux sources d'énergie de remplacement et aux technologies énergétiques compatibles avec l'environnement. Notre nouvelle initiative d'efficacité énergétique et de diversité a été prise en vue de permettre d'atteindre les objectifs sur lesquels on met l'accent dans le rapport de *Confluence énergétique*, ce qui inclut le développement économique et régional, l'efficacité et la productivité de l'industrie, la protection de l'environnement et une étroite collaboration entre le gouvernement et le secteur privé.

• 1550

Lors de la récente réunion intergouvernementale des ministres de l'Énergie qui s'est tenue à Québec, le 29 août, mes collègues provinciaux étaient d'accord avec moi pour affirmer que les gouvernements devraient étudier

[*Traduction*]

In viewing the Advisory Committee's recommendations, we should all bear in mind that the process of deregulation of the natural gas industry has been arduous, but at the same time full of successes. Industry and governments generally have accepted the transition to freely functioning market where buyers and sellers are the ultimate determinants of prices and other contract terms. We should note the achievements to date:

—we have moved much closer to non-discriminatory and open access to markets, transportation and distribution systems;

—distributors are again negotiating for long-term supplies, opting for a portfolio approach to complement their service obligations; and

—governments in general have tried to be supportive in achieving an orderly transition to a well-functioning market.

I am confident that more progress will be made with the passage of time.

There has been strong support from a variety of groups in Canada for the recommendations of the *Energy Options* Report relating to energy efficiency. I was personally very pleased that the advisory committee stressed the importance of a market-based approach as the most cost-effective means of achieving economic efficiency in energy use, while urging government support for technological innovation and development to improve efficiency.

On September 9, I announced that the government will send more than $600 million by 1993 to support energy research on the development and a wide range of activities aimed at energy efficiency and diversity. Under the Energy Research and Development Program, the government will allocate more than $350 million to support research and development. In addition to continuing research in conventional and non-conventional fuels, I have specifically requested that increased resources be allocated to energy efficiency, alternative energy sources, and environmentally compatible energy technologies. Our new Energy Efficiency and Diversity Initiative is designed to achieve the objectives stressed in the *Energy Options* Report, including economic and regional development, industry efficiency and productivity, environmental protection and strong co-operation between government and the private sector.

At the recent intergovernmental meeting of energy ministers in Quebec City, on August 29, my provincial colleagues and I agreed that the report deserves careful study and consideration by governments. As you know, I

[*Text*]

soigneusement le rapport et le prendre en considération. Comme vous le savez, je me suis engagé à répondre publiquement aux recommandations de ce rapport.

Après avoir entendu l'opinion d'un groupe représentant les différents secteurs du public canadien intéressé aux questions énergétiques, je crois, madame la présidente, qu'il est important à ce stade final de l'étude publique de demander à votre Comité de faire connaître son point de vue. Les membres de ce Comité sont élus par les Canadiens et députés de circonscriptions qui sont largement représentatives du public canadien. Je suis également heureux de constater que plusieurs membres du Comité ont une expérience et une expertise très vastes dans les questions touchant la politique énergétique.

C'est donc avec fierté et enthousiasme que je vous soumets: *Les Canadiens et l'énergie*: *au seuil du XXIe siècle*. Plusieurs des questions analysées par le Comité consultatif sont complexes et difficiles. Je vous invite à étudier ce rapport en profondeur et j'attends vos commentaires et vos suggestions.

À mon avis, l'examen que votre Comité fera de ce rapport sera bénéfique à tous les Canadiens, car il leur permettra de mieux comprendre les éléments fondamentaux de la politique énergétique. Vos commentaires ainsi que les conseils que me donneront les fonctionnaires de mon Ministère me seront d'un précieux secours dans la préparation de ma réponse formelle au rapport de *Confluence énergétique*.

Madame la présidente, messieurs, je vous remercie.

The Chairman: Thank you very much, Mr. Minister. We certainly appreciate those opening remarks.

You did mention that Mr. Thomas Kierans was appointed by yourself to be the chairman of Energy Options, and he had a 23-member advisory committee. How were they selected, Mr. Minister?

Mr. Masse: With great care. First of all, we established parameters even before thinking about names. We wanted to be sure every region of the country would be part of the committee and every form or aspect of energy policy would have someone there. Based on those two parameters, we asked for many names through agencies or through lobby groups or through interest groups in different energy sectors.

Having a bank of names, we tried to have people from P.E.I. to B.C., people from the north, people from southern Ontario. There is a mix of all aspects of Canadians. Some came from a university background. Others had a business background. Others were more involved in the lobby aspect of their industry.

After that, you have to ask people if they are interested, and there, sometimes you are surprised: they do not have the time and so on. So it is back to the drawing board. It has taken longer than we thought to select a committee of so many people.

[*Translation*]

am committed to responding publicly to the report's recommendations.

Having heard from a broad cross-section of the Canadian public interested in energy issues, I think that it is important, as a final stage of public review, to solicit the views of your committee, Madam Chairman. Your committee has the advantage of being an elected body whose members represent constituencies broadly representative of the Canadian public. I appreciate also that among the committee members are several individuals with considerable experience and expertise in dealing with energy policy issues.

It is therefore with great pride and enthusiasm that I submit to you *Energy and Canadians*: *Into the 21st Century*. Many of the issues analysed by the Advisory Committee are complex and difficult. I invite you to conduct an in-depth review and I look forward to your comments and suggestions.

In my view, the examination of the report by your committee will pay dividends to all Canadians in terms of a broader understanding of the basic elements of energy policy. Your comments, and the advice that I will seek from my department, will be of great value in the preparation of my formal response to the *Energy Options* report.

Thank you, Madam Chairman.

La présidente: Merci beaucoup, monsieur le ministre. Nous vous remercions de ces remarques préliminaires.

Vous avez dit avoir nommé M. Thomas Kierans président de Confluence énergétique et vous avez ajouté que son comité consultatif comptait 23 membres. Comment ont-ils été choisis, monsieur le ministre?

M. Masse: Nous avons tout d'abord fixé des paramètres avant même de penser à des noms. Nous voulions nous assurer de la représentation de chaque région et des moindres aspects des politiques énergétiques au comité. À partir de ces deux paramètres, nous avons demandé à des organismes ou à des groupes de pression des différents secteurs énergétiques de nous proposer de nombreuses candidatures.

Et nous avons essayé de trouver des gens depuis l'Île-du-Prince-Édouard jusqu'à la Colombie-Britannique, sans oublier le Nord et le sud de l'Ontario. Il y avait des universitaires, des hommes d'affaires et aussi des membres du lobby de leur industrie.

Par la suite, il faut demander à ces gens si la chose les intéresse et là vous avez parfois des surprises, lorsqu'ils vous disent ne pas avoir le temps, par exemple. Il faut donc se consulter à nouveau. Le choix d'un comité regroupant tant de participants nous a pris plus longtemps que prévu.

[*Texte*]

I am very pleased with the committee, the background of the group. They really have worked hard, in the sense that they had many meetings. They had the official meetings, but they had many meetings to prepare the seminars in the country and after that to draft the report, taking into account the research they themselves had asked for in the universities and so on, and try to find a kind of compromise in all that. Most of the recommendations are supported by 100% of the members of the committee. Some have a minority approach, and that is stated in the report.

The reason is to fulfil a Liberal promise of the last 15 years, which is to open the cartographic centre in Sherbrooke.

Mr. MacLellan: You are fulfilling Liberal promises and you are not even fulfilling your own.

Mr. Masse: I can assure you it was easier for you to make the promise than for us to deliver the goods.

Mr. MacLellan: Good gosh, that is a switch.

• 1555

The Chairman: I would just ask the committee's approval to have a seven-minute question period so each person would have time for a first round. Mr. MacLellan.

Mr. MacLellan: Mr. Minister, I do not know how you can ask us to look at this constructively and to comment on it when you are not even approving of it yourself. The comments you made when this report was made public were similar to the comments you might have made if you were asked to comment on *The Communist Manifesto*. I mean, you distanced yourself completely from the report. I just want to know if you favour this report. Do you think this is a good report?

Mr. Masse: What I explained right at the beginning, in April, 1987, was first of all we would have the public consultation process, and after that the report should be tabled with the House of Commons committee, this one. Then the people, the members of the House, would have a chance to have their own input in the discussions and that would give an opportunity for people outside the committee to come and explain what they think about the recommendations of the committee and explain if they agree or disagree with one or another aspect of the committee.

There you will formulate your report and that is there in my thinking. We have two months—something of that kind—to answer. For me, that was the place where as the Minister of Energy I would answer to the committee. If in the middle of the process I would have taken the opportunity to explain all my thinking, your first question would be why the hell are we here, Mr. Minister, because you have already stated your recommendations.

Mr. MacLellan: I think you anticipated a question that probably most Canadians are asking, which is why did

[*Traduction*]

Je suis très satisfait du comité et de l'expérience de ses membres. Ils ont vraiment beaucoup travaillé car ils ont tenu de nombreuses réunions. Il y a en a eu d'officielles, mais beaucoup d'autres aussi, pour préparer des colloques à l'échelle du pays; par la suite ils ont dû rédiger le rapport en tenant compte des recherches qu'ils avaient confiées aux universités et à d'autres groupes et en essayant de trouver une sorte de moyen terme dans tout cela. L'ensemble des membres du Comité appuient la plupart des recommandations. Certains ont une perspective divergente, comme l'indique le rapport.

Il s'est agi de tenir une promesse qu'avaient faite les Libéraux il y a 15 ans, celle d'ouvrir le Centre de cartographie à Sherbrooke.

M. MacLellan: Voilà que vous tenez les promesses des Libéraux sans pouvoir même tenir les vôtres.

M. Masse: Je peux vous assurer qu'il vous a été plus facile à vous de faire des promesses qu'à nous de les réaliser.

M. MacLellan: C'est le monde à l'envers!

La présidente: Voudriez-vous que chacun dispose de sept minutes de questions pour que vous ayez tous le temps pour un premier tour? Monsieur MacLellan.

M. MacLellan: Monsieur le ministre, comment pouvez-vous nous demander d'examiner ce rapport de façon constructive et de le commenter alors que vous ne l'approuvez même pas vous-même? Lorsqu'il a été rendu public, les commentaires qu'il vous a inspirés étaient semblables à ceux que vous auriez pu faire si l'on vous avait demandé de commenter le *Manifeste communiste*. Je veux dire par là que vous vous en êtes complètement distancié. J'aimerais savoir si vous appuyez ce rapport. Vous paraît-il valable?

M. Masse: Ce que j'ai expliqué au tout début, en avril 1987, c'est qu'il fallait tout d'abord organiser un processus de consultations publiques après lesquelles le rapport serait déposé au comité de la Chambre des communes, ce comité-ci. Par la suite, les gens, les députés, auraient la possibilité de participer aux discussions et d'inviter d'autres personnes à venir expliquer ce qu'elles pensent des recommandations du Comité tout en disant s'ils approuvent ou non certaines de ses caractéristiques.

Par la suite, ce sera à vous d'élaborer votre rapport et vous disposez d'environ deux mois pour le faire. C'est à ce stade que je pourrai répondre au Comité en tant que ministre de l'Énergie. Si au cours du processus, je vous expliquais le fond de ma pensée, vous vous demanderiez aussitôt: à quoi cela sert de discuter, puisque vous avez déjà exposé vos recommandations?

M. MacLellan: Je pense que vous avez déjà prévu une question que se posent probablement la plupart des

[*Text*]

you want this report. And if it means something why did the government go against it, particularly with respect to mega-projects?

You say that such a criticism would be totally unjustified because our approach to mega-projects is fully consistent with the *Energy Options* report, which acknowledged that incentives might be provided for mega-projects for reasons such as employment creation and regional industrial benefits and urged governments to state this explicitly. We have done so.

But no, the reports I have read on the Hibernia and the Lloydminster upgrader have not indicated that the government looks upon those as regional development projects at all. They look upon those as energy projects. Yet *Energy Options* states that if governments choose to support mega-projects for other reasons such as regional development, the fiscal treatment should be designed to avoid distortion or confusion of energy policy objectives.

There is absolutely no relation to what you have done in the last few months with what is recommended in *Energy Options*, nor what you have said in stating that the market should dictate the activity in the energy sector. I find that somewhat incredible.

M. Masse: Premièrement, madame la présidente, je crois qu'en tant que ministre de l'Énergie, je me dois de tenir compte dans les décisions que l'on prend d'un certain nombre de recommandations, de suggestions, de politiques qui proviennent de différents secteurs de l'activité gouvernementale ou même de différents paliers de gouvernements.

Souvenons-nous que, ici même à Ottawa, la première conférence fédérale-provinciale des ministres de l'Énergie a été tenue il y a déjà un an et demi et elle portait sur la sécurité des approvisionnements. C'était la première conférence que nous avions, des huit années précédentes, qui a porté là-dessus; à ce moment-là, une des conclusions de l'analyse de la discussion avec les ministres provinciaux c'était que le gouvernement du Canada doit attacher une importance fondamentale à la sécurité des approvisionnements.

À la suite de cette réunion-là, en accord avec les ministres, nous avons formé un groupe de travail de fonctionnaires en provenance des provinces et du gouvernement fédéral pour discuter de cette question-là, et des recommandations ont été faites à savoir qu'il faut passer à l'action dans un certain nombre de champs lorsque c'est techniquement faisable pour assurer dans cinq, six, sept ou dix ans, une sécurité énergétique que nous avons maintenant. Première source donc, d'information ou de politique.

[*Translation*]

Canadiens, à savoir pourquoi vous avez voulu ce rapport. S'il a vraiment un sens, pourquoi le gouvernement s'y est-il opposé, notamment en ce qui concerne les mégaprojets?

Vous dites qu'un tel reproche serait tout à fait injustifié car, pour ces projets, vous appuyez pleinement les recommandations du rapport de *Confluence énergétique*, selon lesquelles on pourrait encourager les mégaprojets qui permettent la création d'emplois aussi bien que d'avantages industriels régionaux, de sorte que les gouvernements devraient l'indiquer clairement. Vous dites l'avoir fait.

Mais ce n'est pas le cas: d'après les rapports que j'ai lus sur Hibernia et l'usine de préraffinage de Lloydminster, il ne semble pas du tout que le gouvernement les considère comme des projets de développement régional mais plutôt comme des projets énergétiques. Or, *Confluence énergétique* a indiqué que si les gouvernements décident d'appuyer des mégaprojets pour des raisons autres que le développement régional, il faut leur faire un traitement fiscal qui permette d'éviter la distorsion ou la confusion des objectifs de la politique énergétique.

Il n'existe absolument aucun lien entre ce que vous avez accompli ces tout derniers mois et les recommandations de *Confluence énergétique* ou ce que vous avez dit à propos du marché, qui devrait dicter ses activités au secteur énergétique. Je trouve cela quelque peu incroyable.

Mr. Masse: First of all, Madam Chairman, I think that as Minister of Energy I must take into account in the decision taken a certain number of recommendations, suggestions, and policies coming from different sectors of government activity or even different levels of government.

Let us not forget that here in Ottawa, the first federal-provincial conference of energy ministers took place as much as a year and a half ago and that it dealt with security of supply. In eight years, it was the first conference to deal with this topic; one of the conclusions of the discussions with the provincial ministers was that the Government of Canada must consider security of supplies a key element.

After that meeting and agreement with the ministers, we established a task force of civil servants representing the provinces and the federal government to discuss that question, and it was recommended that we act in a certain number of fields, when it is technically feasible, to ensure within five, six, seven, or ten years, the energy security we now have. So that is one source of information or policy.

[*Texte*]

• 1600

La deuxième source d'information ou de politique, c'est l'énoncé de principe que j'ai déposé à Edmonton, le lendemain du discours du Budget fait par M. Wilson au mois de juin de l'année dernière. Dans ce document, on a expliqué les critères dont le gouvernement allait tenir compte lors de discussions ou lors d'ententes avec des consortiums concernant les mégaprojets.

La troisième source de consultation est le rapport dont nous discutons aujourd'hui. Ce rapport ne met pas en cause la politique du gouvernement. Il précise qu'il y a lieu d'assurer le développement énergétique au Canada, mais que ce développement énergétique doit être fait comme tel, et que si le gouvernement a des raisons supplémentaires de le faire, il doit les spécifier et les expliquer.

Ce rapport était public lorsque nous avons annoncé le premier mégaprojet depuis plusieurs années au Canada, celui d'Hibernia. Je me souviens fort bien que le gouvernement a clairement expliqué que le projet Hibernia était un projet essentiel à la construction du Canada et un investissement important pour cette région du pays, et que c'était, par conséquent, un très important projet de développement régional dans le secteur énergétique. Ce projet de développement régional aurait pu être dans un autre domaine. C'est un projet dans le domaine de l'énergie parce que c'est cette sorte de richesse naturelle que nous avions à mettre en valeur.

Le gouvernement a clairement expliqué son approche et clairement montré ses couleurs. Dans ce sens-là, il a répondu parfaitement à la demande faite dans le rapport *Confluence énergétique*. Il en a été de même dans le cas des autres projets que nous avons annoncés depuis.

The Chairman: If we have time, we will come back to you, Mr. MacLellan.

Mr. Masse: I want to make sure that everybody understands this. I will read the paragraph about that in French.

C'est à la page 94: Mégaprojets.

> Au chapitre II, le Comité consultatif a fait remarquer que le gouvernement ne devait pas nécessairement accorder un appui spécial aux mégaprojets énergétiques pour des raisons de sécurité énergétique. Nous croyons que les régimes fiscaux actuels ne conviennent peut-être pas aux mégaprojets. Si les gouvernements choisissent d'appuyer les mégaprojets pour d'autres raisons, par exemple, le développement régional, il faudra penser à des mesures fiscales qui permettront d'éviter toute distorsion et toute confusion dans les objectifs de la politique énergétique.

Je pense que nous avons tenu compte de cet aspect du rapport, et nous l'avons clairement indiqué.

Mr. Nystrom: I welcome the minister to the committee. I want to continue the same lines of questioning as Mr. MacLellan. But before that, perhaps you could tell the

[*Traduction*]

The second source of our information or policy is the declaration of principle I presented in Edmonton in June of last year, the day after Mr. Wilson made his budget speech. In that statement I explained what criteria the government would use in its discussions or agreements with consortiums on megaprojects.

The third source of advice is the report we are discussing today. It does not question government policy. It says that energy development in Canada must be ensured, but that it must be done in such a way as to meet energy objectives and that if the government has other reasons to act, it must give those reasons and explain them.

The report had already been made public when we announced Hibernia, the first megaproject in years in Canada. I remember very well that the government clearly explained that Hibernia was essential to the development of Canada, that it was an important investment for the region and that, consequently, it was a very important regional development project in the energy sector. It could have been in another sector. It has taken place in the energy sector because that was the natural resource that was there to develop.

Government clearly explained its approach and laid its cards on the table. In that sense it has done as the *Energy Options* report asks. And the same is true of other projects which have been announced since.

La présidente: Monsieur MacLellan, vous aurez un autre tour si nous en avons le temps.

M. Masse: Je veux m'assurer que tout le monde comprenne bien. Je vais vous lire le paragraphe qui porte là-dessus.

It is on page 85: Megaprojects.

> In chapter 2, the Advisory Committee noted that there should be no need to provide extraordinary government support for energy megaprojects for energy security reasons. We recognize that megaprojects may not fit easily within existing fiscal regimes. If governments choose to support megaprojects for other reasons, such as regional development, the fiscal treatment should be designed to avoid distortion or confusion of energy policy objectives.

I think we have taken into account that aspect of the report, and we have said so clearly.

M. Nystrom: Je souhaite la bienvenue au ministre. Je vais continuer dans la même veine que M. MacLellan. Mais auparavant, peut-être pourriez-vous dire au Comité

[*Text*]

committee what the response has been from your provincial colleagues to the *Energy Options* report.

Mr. Masse: I will tell you from my own memories, and I want to be just with everybody. Alberta raised some questions about the provincial rights and the fiscal regime that we already have between Canada and Alberta. They were worried about some of the energy option recommendations. Quebec has raised some questions about the electricity aspect of the report, the transmission lines. Those are the two provinces that have been most vocal on this question.

At the end June, when I met with the provinces, I tabled the report. I have sent them a letter, asking them to prepare their thinking about the report. They will have two or three options: they can appear here and answer your questions and make their statements; they can write directly to the ministers; or they can have discussions with the department officials, which would help me to prepare the public answer.

• 1605

Mr. Nystrom: Switching to what Russ was asking about—that is, mega-projects—without repeating a lot of stuff, on page 41 of *Energy Options* a certain amount of doubt is cast on the economic wisdom of mega-projects.

I want to then switch to Lloydminster. In principle, I have nothing at all against the development of Lloydminster. It is in my own province, and indeed an upgrader there may be a tremendous idea down the road ahead. But one of the problems we have is the uncertainty of the price of oil in the future. It was said that it has to be around $25 a barrel before it is economic. Today it is around $14 or $15 a barrel.

I wonder if you can shed any more light for the committee, in addition to what we have had from the press and so on, as to the reason for the go-ahead at this time. Certain cynics such as Len Gustafson would say it might be election timing, but I do not really believe him.

I also wanted to ask you this, Mr. Minister, perhaps even before you answer that. It was noted with a bit a curiosity in the Prairies that you were not there for the announcement, and this is a pretty big announcement of a pretty major project. Other ministers were there and you were not. I assume you were otherwise occupied, but I wonder if you could tell us why you were not there. It obviously raised a few eyebrows.

Mr. Masse: You have raised many questions. I will try to give you a couple of answers, and if I forget one question, please come back.

Premièrement, en ce qui concerne la question des prix de l'avenir lors d'une décision sur un mégaprojet, il est évident qu'actuellement, les arguments de l'un peuvent valoir les arguments de l'autre, puisqu'on ne sait pas

[*Translation*]

ce qu'ont pensé vos homologues provinciaux du rapport de *Confluence énergétique*.

M. Masse: Je vais me fier à ma mémoire, et je tiens à être juste envers tout le monde. L'Alberta a soulevé des questions concernant les droits provinciaux et l'entente fiscale qui existe entre le Canada et l'Alberta. Certaines recommandations faites dans le rapport ont suscité des craintes dans cette province. Le Québec avait des questions à propos de l'électricité, des lignes de transport de l'électricité. Ce sont les deux provinces qui ont eu le plus à dire sur la question.

À la fin juin, lorsque j'ai rencontré les représentants des provinces, j'ai déposé le rapport. Je leur ai envoyé une lettre leur demandant de donner leur avis. Elles ont deux ou trois options: elles peuvent comparaître devant le Comité pour répondre à vos questions et faire leur déclaration; elles peuvent écrire directement aux ministres; ou elles peuvent s'adresser aux fonctionnaires du ministère, ce qui m'aiderait à préparer la réponse officielle.

M. Nystrom: Pour passer à ce dont parlait Russ—c'est-à-dire aux mégaprojets—sans trop ressasser les mêmes choses, on peut voir à la page 43 du rapport que les auteurs mettent en doute la sagesse économique des mégaprojets.

Passons maintenant à Lloydminster. En principe, je n'ai rien contre le développement de Lloydminster. C'est dans ma province, et il se peut fort bien qu'une usine de préraffinage s'avère une excellente chose à l'avenir. Mais nous ne savons pas quel sera le prix du pétrole dans l'avenir. On a dit qu'il fallait qu'il atteigne 25$ le baril pour que le projet soit rentable. Le pétrole se vend aujourd'hui environ 14$ ou 15$ le baril.

Je me demande si vous pouvez expliquer au Comité, avec un peu plus de précisions que ce que nous avons pu lire dans la presse, la raison qui vous a poussés à aller de l'avant maintenant. Certains cyniques, comme Len Gusfafson, diraient que c'est en rapport avec la campagne électorale qui s'annonce, mais je ne le crois pas vraiment.

Je voudrais vous poser une autre question, monsieur le ministre, à laquelle je vous demanderais peut-être de répondre en priorité. On a remarqué avec quelque étonnement dans les Prairies que vous n'étiez pas présent lorsque l'on a annoncé ce projet d'une assez grande importance. D'autres ministres étaient là, mais vous étiez absent. Je suppose que vous étiez pris, mais je me demande si vous pouvez nous expliquer votre absence. Il est évident qu'elle a surpris.

M. Masse: Vous avez soulevé de nombreuses questions. Je vais essayer d'y répondre, et si j'en oublie une, n'hésitez pas à me la rappeler.

First of all, as regards the question of oil prices in the future in the context of deciding on a megaproject, it is obvious that one man's guess is as good as the other's, since no one knows what the situation will be 10, 15, or

[*Texte*]

quelle sera la situation dans 10, 15 ou 20 ans. C'est à ce moment-là qu'on jugera si la décision a été largement favorable au Canada ou si, au contraire, elle a causé des problèmes, particulièrement dans le domaine de la mise en valeur des ressources naturelles où le prix international fluctue continuellement.

Les Canadiens ont dû prendre des décisions de ce genre à maintes reprises au cours de leur histoire. Lorsqu'il s'est agi d'établir un réseau de chemins de fer au Canada, les députés ont sans doute eu des discussions semblables à celles d'aujourd'hui sur la sagesse d'investir autant d'argent dans les chemins de fer. Il en a été de même lorsque le gouvernement Bennett, en 1936, a décidé d'établir un réseau national de radio, CBC-Radio-Canada, au moment où ce type d'industrie en était à ses débuts. La même chose s'est produite—je m'en souviens fort bien parce que c'est plus près de nous—lors de la canalisation du Saint-Laurent et de l'établissement des écluses sur le fleuve Saint-Laurent, à Montréal, à la fin des années 50. Encore là, on se posait des questions sur la sagesse de ces investissements publics.

Je vous donne ces exemples et je pourrais vous en donner d'autres. Vous en connaissez vous-mêmes dans votre province. Il y a toujours un moment où il y a une décision à prendre avec les éléments qu'on a à ce moment-là, compte tenu de nos prévisions sur les prix de l'avenir. Je ne peux pas vous parler de l'avenir, mais je peux vous assurer que ces décisions ont été prises en collaboration avec un ensemble de participants, tant du secteur privé que des provinces, avec des fonctionnaires et des experts-conseils de l'extérieur qui ont fait des analyses sur ces questions-là.

Si le gouvernement canadien avait agi seul, vous pourriez dire, à la limite: Oui, mais vous êtes le seul à penser ainsi. Mais dans tous ces projets-là, honnêtement, nous sommes nombreux autour de la table. Dans le cas du projet Hibernia, il y a au moins cinq sociétés privées qui ont toutes intérêt à assurer des profits à leurs actionnaires. Il y avait également là une province, soit Terre-Neuve. Dans le cas du projet de Lloydminster, encore là, il y a une société privée, Husky, ainsi que deux provinces qui ont intérêt à ce que les analyses soient le plus valables possible, compte tenu de ce qu'on connaît aujourd'hui de l'avenir. Il en est ainsi pour d'autres projets dont nous discutons actuellement au ministère de l'Énergie, des Mines et des Ressources.

Parlons maintenant de la question de la période où les annonces se font. Ces projets-là ne se décident pas en l'espace de deux mois, honnêtement, ni en l'espace d'une semaine. Ils nécessitent des années de discussion et des mois de négociation.

• 1610

Le projet Hibernia est l'un des premiers projets auxquels j'ai eu à m'intéresser lorsque je suis arrivé au Ministère au mois de juillet, il y a deux ans. Une des premières réunions que j'ai eues avec le secteur pétrolier

[*Traduction*]

20 years from now. That is when we will be able to judge if a decision was good for Canada or if, on the contrary, it has been a source of problems, particularly in natural resource development where international market prices are always fluctuating.

Canadians have had to make many such decisions in their history. When the decision had to be made to build a railway line in Canada, the members at the time probably had the same type of discussion we are having today on the wisdom of investing so much money in railways. The same thing happened in 1936 when the Bennett government decided to create a national radio network, CBC, at a time when radio was a fledgling industry. And it was the same thing—and I remember that very well because it is closer to us in time—for the construction of the St. Lawrence seaway and of the locks in Montreal at the end of the 1950s. Then, too, there were questions about the wisdom of such public investments.

I am giving you those examples and I could find others. You are aware of some in your own province. There always comes a time when you have to make a decision with the information available at that time and while taking into account projections of future prices. I cannot foretell the future, but I can assure you that these decisions were made in consultation with a number of participants from the private sector as well as the provinces, with public servants and outside consultants who have done studies on those questions.

If the Canadian government had acted alone you could maybe say: Yes, but you are the only one to think that way. However, I can say truly that for all those projects there were many people around the table. In the case of Hibernia, there were at least five private companies which all had an interest in guaranteeing a profit to their shareholders. There was also a province, Newfoundland. In the case of Lloydminster, there was again one private company, Husky, as well as two provinces which were interested in seeing that the best possible analysis was done with the data then available for the future. And the same is true of other projects that we are discussing at present within the Department of Energy, Mines and Resources.

Let us come now to the question of the time chosen for the announcement. Such projects cannot be decided in a couple of months nor in a week. They take years of discussions and months of negotiations.

Hibernia was one of the first projects I had to deal with when I came to the department in July two years ago. One of the first meetings I had with the oil industry was held in Vancouver and dealt with this very project.

[*Text*]

a eu lieu à Vancouver et portait déjà sur le projet Hibernia. Les représentants du secteur privé et de la province concernée se rencontraient à cette réunion d'il y a presque deux ans et demi.

Depuis cette époque, il y a eu des hauts et des bas. Il y a eu des discussions au Canada, aux États-Unis et dans l'ensemble des provinces. Il y a eu des réunions concernant Hibernia dans pratiquement toutes les villes du Canada. Il arrive un moment où nous nous sommes entendus et où nous sommes prêts à faire l'annonce. Il en est de même dans le cas du projet de Lloydminster.

La question que vous posez, à mon avis, est la suivante: les gouvernements doivent-ils administrer pendant la durée de leur mandat ou si, au contraire, il doit y avoir un code d'éthique ou un amendement à la Constitution canadienne prévoyant que lorsque la presse ou les partis d'opposition voient des objections à une chose, les gouvernements doivent cesser d'administrer sans qu'il y ait une élection? Si telle est votre suggestion, je veux bien qu'on en discute. Cependant, qu'on en discute ouvertement et qu'on cesse de croire qu'un gouvernement qui administre pendant la durée de son mandat est un gouvernement qui sent les élections.

The Chairman: We will have to come back to you, Mr. Nystrom.

Mr. Masse: I am not sure whether I have forgotten one question.

The Chairman: He did have another question. That is right, Mr. Minister.

M. Nystrom: Pourquoi le ministre n'était-il pas là?

M. Masse: Pourquoi le ministre n'était-il pas à Lloydminster?

M. Nystrom: Oui.

M. Masse: D'abord, le ministre était déjà allé à Lloydminster, je tiens à vous le dire. Deuxièmement, cette fin de semaine-là j'étais—osons dire le mot—en vacances au Québec, dans les Laurentides, et le gouvernement était amplement représenté par deux ministres des deux provinces concernées, par M. Mazankowski et par M. Bill McKnight. Tous ces gens-là ont certainement attiré suffisamment la presse pour que la population canadienne soit renseignée sur le projet.

Mr. Gagnon: Madam Chairman, I have three points I would like to raise, if I could get them all in in the seven minutes.

Mr. Minister, you found $400 million for the Husky upgrader. It is benefiting one oil company. Would you consider extending the Canadian Exploration and Development Incentive Program another year to help the other 599 companies out there as well as the drillers? Their cashflow is estimated as being down 22% this year over last year.

[*Translation*]

Representatives of the private sector and the province were already meeting two years and a half ago.

Since that time, there have been ups and downs. Discussions were held in Canada, in the United States, and in all provinces. Meetings were organized on Hibernia in almost all Canadian cities. At a certain point an agreement was reached and we were ready to make the announcement. The same thing applies to the Lloydminster project.

I think you are asking the following question: Should the role of government be to govern during its term of office, or should there be a code of ethics or an amendment to the Constitution stating that when the press or the opposition parties object to something, the government should cease governing until an election? If that is what you are suggesting, I do not mind discussing it. However, let us talk openly about it and stop saying that a government that governs is only thinking about the coming elections.

La présidente: Nous devrons revenir à vous, monsieur Nystrom.

M. Masse: Je me demande si je n'ai pas oublié une question.

La présidente: En effet, monsieur le ministre, le député avait une autre question.

Mr. Nystrom: Why was the minister not there?

Mr. Masse: Why the minister was not in Lloydminster?

Mr. Nystrom: Yes.

Mr. Masse: First of all, I want to stress that the minister had already been in Lloydminster. Secondly, let me be frank and say that I was holidaying in the Laurentians that weekend, and that the government was very well represented by two ministers from the provinces concerned, Mr. Mazankowski and Mr. Bill McKnight. I am sure all these people attracted enough media attention to have the Canadian public well informed on the project.

M. Gagnon: Madame la présidente, j'ai trois observations à faire, si mes sept minutes le permettent.

Monsieur le ministre, vous avez trouvé 400 millions de dollars pour l'usine de préraffinage Husky qui ne profitent qu'à une société pétrolière. Accepteriez-vous de prolonger pendant un an encore le Programme canadien d'encouragement à l'exploration et à la mise en valeur pour aider les 599 autres sociétés ainsi que les compagnies de forage? On estime que leur marge d'autofinancement a subi une baisse de 22 p. 100 cette année par rapport à l'an dernier.

[*Texte*]

M. Masse: Premièrement, je peux vous assurer que l'intérêt que nous portons au secteur énergétique touche tous les secteurs et toutes les sociétés impliqués dans le domaine énergétique, dans l'une ou l'autre des provinces ou dans l'un ou l'autre des domaines.

Deuxièmement, le gouvernement n'a pas craint, lorsque cela a été nécessaire, d'apporter une aide de plusieurs centaines de millions de dollars au secteur énergétique, que ce soit dans les mines ou dans le secteur pétrolier, dans le cadre des programmes que vous connaissez.

Troisièmement, je suis bien au courant de la situation que vous décrivez. J'ai eu l'occasion, entre autres à la demande de M^me^ la présidente, de rencontrer les gens des groupes intéressés. Cette semaine—je crois que c'est lundi matin, à 8h30—à mon bureau, nous avons discuté de cette question. Depuis, des rencontres ont eu lieu entre les représentants des groupes que vous mentionnez et les fonctionnaires de mon Ministère. Je devrais être en mesure de faire des recommandations à mes collègues sur la question que vous soulevez au cours des prochains jours.

Mr. Gagnon: The second point I would like to raise is regarding the Cold Lake project that Imperial Oil undertook. It was one of the first things you visited when you took on your new portfolio. Their original proposal was to spend in excess of $11 billion and build one massive plant. They have changed that to build in stages. They would build a stage, get it on-stream, and build another stage. The concept is the same sort of concept Esso had in the original Cold Lake project—in other words, there will be no cashflow until the entire plant is built.

• 1615

There was a much different concept proposed to your predecessor three years ago called the Cascade approach, where 5,000 barrel increments were added to a plant. The experts—Triad Engineering Services Ltd., a very well recognized Calgary firm—believed at the time that they could produce the plant in the neighbourhood of $10,000 per barrel of capacity versus the estimated $25,000 per barrel of capacity. I notice the current estimate of Husky is in the magnitude of $27,000 and change.

The benefits of course are first and foremost that you lower capital costs, which means better economics; you have a much more stable work force; you build one increment, then a second and a third increment; much more can be done in Canada, which means many more jobs in Canada. Inasmuch as we have a $400 million investment in this, I wondered why you have not had a good look at this other concept of incremental approach, or have we?

[*Traduction*]

Mr. Masse: First, I can assure you that we are interested in all sectors and all companies of the energy industry, in whatever province and whatever field.

Secondly, when the need was there, the government did not hesitate to help the energy sector with several hundred millions of dollars, under the different programs.

Thirdly, I am well aware of the situation you describe. I had the opportunity, at the request of the Chairman among others, to meet the concerned groups. We even discussed the matter in my office this week, I think it was Monday morning at 8.30. Since then, meetings were held between representatives of the groups mentioned and my officials. I should be able to make recommendations to my colleagues on that matter in the coming days.

M. Gagnon: Deuxièmement, j'aurais une question au sujet du projet de Cold Lake entrepris par la compagnie pétrolière Impériale. C'est un des premiers projets que vous avez visités à votre arrivée au ministère. Cette société proposait à l'origine de consacrer plus de 11 milliards de dollars à la construction d'une énorme usine. Elle a maintenant changé d'avis et prévoit construire par étapes. Elle construirait une phase, la mettrait en service, et en construirait une autre ensuite. Il s'agit du même genre de concept que celui que proposait la société Esso au départ pour le projet Cold Lake, autrement dit, il n'y aura pas de mouvement de trésorerie avant que toute l'usine ne soit construite.

Il y a trois ans, on avait proposé à votre prédécesseur un concept tout à fait différent qui s'appelait le procédé en cascade et où on ajoutait à une usine des suppléments de capacité de 5,000 barils. Les spécialistes—de Triad Engineering Services Ltd., une entreprise réputée de Calgary—estimaient à l'époque qu'ils pourraient ainsi arriver à une production d'environ 10,000$ le baril de capacité plutôt que les 25,000$ prévus. Je remarque qu'on prévoit à l'heure actuelle un chiffre de 27,000$ pour Husky.

Évidemment, le principal avantage est qu'on abaisse les coûts en immobilisations, ce qui est plus rentable; on a une main-d'oeuvre beaucoup plus stable; on construit par phases; on peut faire beaucoup plus au Canada, ce qui veut dire plus d'emplois. Étant donné que nous investissons 400 millions de dollars dans ce projet, je me demande pourquoi vous n'avez pas envisagé cet autre procédé, ou peut-être l'avez-vous fait?

[*Text*]

Mr. Masse: Sir, we have many projects that we are working on in the department. Some have already been announced. Others are, as we say, in the pipeline to be discussed.

Mr. George Anderson is the deputy minister responsible for that aspect of the department. With your permission, I will ask him to comment on Mr. Gagnon's remarks on these matters.

Mr. George Anderson (Assistant Deputy Minister, Energy Policy Sector, Department of Energy, Mines and Resources): When we were considering the Lloydminster project, we did look at a very wide number of options. I think we reviewed a dozen different concepts of how to upgrade oil in that area. Even very recently, we looked very carefully at the question of what the economics of a reduced size of upgrader would be, and we paid particular attention, as was said in some of the press interviews at the time we announced the Lloydminster upgrader, to a 10,000 barrel a day CANMET upgrader. Others were looked at, and we had a number of people come and talk to us about others.

What we found is that for virtually all of these, when you are dealing with a stand alone upgrader, the economics of these smaller units on a per-barrel basis did not compare with the economics of a 20,000 or 25,000-barrel-a-day unit.

In fact, we will get better economics with further investment on the current Lloydminster proposal. We reckon that if we double the size of the Lloydminster upgrader, the second train would probably have economics somewhere in the vicinity of 65% to 75% the cost per barrel that the first train has. That is because you will have some of the existing infrastructure and some economies of scale associated with the first plant. But we never did find a smaller or phased approach to this where we would get better economics from doing a smaller project.

Mr. Gagnon: I would like to make two comments. First, there is no doubt that the operating efficiency in a larger plant is better than a smaller one. But when you can build it for approximately 40% of the cost, the economic efficiency is better for the smaller one, according to the experts.

Secondly, you are talking about economies of scale. I think you have also given a good reason why the plant should not have been in Lloydminster. It should have been tied with an existing refinery, such as was done with the co-operative refinery.

The third thing I would like to ask the minister directly has to do with a very pointed recommendation on page 32. This refers to the naughty problem of where we have access of electrical lines from one province across another. We do see one province, Newfoundland, that has vast quantities of untapped hydro-electric. We have environmental problems using fossil fuels, and certainly if we can tap these continuous renewable resources such as

[*Translation*]

M. Masse: Monsieur, nous travaillons sur un grand nombre de projets au ministère. Certains ont déjà été annoncés. D'autres feront bientôt l'objet de discussions.

M. George Anderson est le sous-ministre responsable de cet aspect au ministère. Avec votre permission, je lui demanderai de répondre à M. Gagnon.

M. George Anderson (sous-ministre adjoint, Secteur de la politique énergétique, ministère de l'Énergie, des Mines et des Ressources): Lorsque nous avons étudié le projet Lloydminster, nous avons en effet considéré un grand nombre d'options. Je pense que nous avons étudié une douzaine de concepts différents sur la façon de valoriser ce pétrole. Même tout récemment, nous avons regardé de très près la possibilité d'avoir une usine de dimensions réduites, et aussi, comme on l'a dit dans la presse au moment de l'annonce de l'usine de valorisation de Lloydminster, nous avons envisagé une usine CANMET de 10,000 barils par jour. D'autres options ont été étudiées, et différents spécialistes ont été consultés.

Nous avons constaté que dans presque tous les cas, lorsqu'il s'agit d'une usine de valorisation autonome, les petites unités sont beaucoup moins rentables qu'une unité de 20,000 à 25,000 barils par jour.

En fait, ce sera encore plus rentable si on continue d'investir dans le projet Lloydminster actuel. En effet, si on double la dimension de l'usine de valorisation de Lloydminster, la deuxième phase de valorisation coûtera de 65 p. 100 à 75 p. 100 de moins que la première le baril. Cet état de choses découle du fait que l'infrastructure existera déjà et que des économies d'échelle pourront être réalisées. Mais nous n'avons jamais constaté qu'un projet de moindre envergure serait plus rentable.

M. Gagnon: J'aimerais faire deux observations. Premièrement, il est évident qu'une grande usine est plus efficace du point de vue de l'exploitation qu'une plus petite. Mais si la construction coûte environ 40 p. 100 du coût, l'unité plus petite est plus rentable selon les experts.

Deuxièmement, vous parlez d'économies d'échelle. Voilà aussi une bonne raison pour laquelle cette usine n'aurait pas dû se trouver à Lloydminster. Elle aurait dû être reliée à une raffinerie existante, comme dans le cas de la coopérative.

Ma troisième question se rapporte directement à une recommandation très significative à la page 32. Il s'agit du problème épineux que pose l'accès aux lignes électriques d'une province à l'autre. Une province, Terre-Neuve notamment, dispose de vastes quantités d'hydro-électricité encore inutilisées. La consommation des combustibles fossiles pose des problèmes du point de vue de l'environnement, et il vaudrait certainement mieux

[*Texte*]

hydro-electric, it is good. We do have a problem with transportation in Quebec.

Are you prepared to take that recommendation and play a major role in trying to bring these two together and get on with the development of this major resource?

• 1620

M. Masse: Voilà une question fort complexe qui est soulevée par le rapport. J'en ai saisi mes collègues des provinces lors de la réunion du mois d'août, où j'ai eu l'occasion d'exposer les principes de base de l'assouplissement de la réglementation concernant l'exportation de l'électricité.

Au cours des mois précédents, le gouvernement canadien avait encouragé le Québec et Terre-Neuve à discuter des questions de développement des ressources hydrauliques intéressant à la fois Terre-Neuve et le Québec. Des rencontres fréquentes et directes ont eu lieu entre les provinces, et le gouvernement du Canada en est satisfait.

D'autre part, l'Île-du-Prince-Édouard présente un problème particulier. Encore là, j'ai rencontré à maintes reprises le ministre du Québec et le ministre de l'Île-du-Prince-Édouard pour m'assurer qu'il y ait un transfert d'électricité entre le Québec et l'Île-du-Prince-Édouard. Vous savez que, pour aller d'une province à l'autre, il faut traverser le Nouveau-Brunswick et que le Nouveau-Brunswick a son mot à dire à ce sujet.

J'ai été fort heureux de constater, au cours des semaines qui ont précédé l'annonce de l'assouplissement de la réglementation, qu'une entente était intervenue entre l'Île-du-Prince-Édouard, le Nouveau-Brunswick et le Québec sur ces matières, et qu'il était donc possible de livrer de l'électricité du Québec à l'Ile-du-Prince-Édouard en passant par le Nouveau-Brunswick. C'est là la preuve qu'il y a possibilité, dans un système déréglementé, d'encourager les provinces à améliorer le commerce interrégional ou interprovincial.

Dans ce même esprit, ayant annoncé la déréglementation ou l'assouplissement de la réglementation concernant l'exportation de l'énergie, j'ai fait parvenir hier, ou avant-hier, au président de l'Office national de l'énergie les principales recommandations concernant le commerce interprovincial de l'électricité. J'ai demandé à l'Office national de l'énergie de tenir des audiences publiques sur ces questions-là, au même titre que j'avais demandé à l'Office, en septembre 1986, de tenir des audiences publiques sur l'assouplissement de la réglementation en matière d'exportation.

J'ai également communiqué avec mes collègues des provinces pour leur faire part de cette décision et leur demander de faire valoir leur point de vue, s'il y a lieu, à l'Office national de l'énergie au cours des prochains mois

[*Traduction*]

utiliser ces sources d'énergie renouvelable comme l'hydro-électricité. Il y a toutefois un problème de transport avec le Québec.

Êtes-vous disposé à agir sur cette recommandation et à contribuer de façon importante à réunir ces deux intervenants pour assurer la mise en valeur de cette ressource importante?

Mr. Masse: This is a very complex issue that is being raised in the report. I submitted it to my provincial colleagues at the August meeting when I had the opportunity to explain the basic principles for easing the regulation respecting the electric power exports.

During the previous months, the federal government had encouraged Quebec and Newfoundland to discuss matters related to the development of hydraulic resources which concerned both Quebec and Newfoundland. The provinces met directly and frequently, and the federal government is satisfied with those meetings.

On the other hand, the Province of Prince Edward Island has a particular problem. Once again, I have met several times with the ministers from Quebec and Prince Edward Island in order to make sure that there would be a transfer of electricity between Quebec and Prince Edward Island. As you know, in order to go from one province to the other, one has to go through the Province of New Brunswick which is entitled to have its say in the matter.

I was quite pleased to see that during the weeks preceeding the announcement of the deregulation, an agreement was reached between Prince Edward Island, New Brunswick and Quebec on this matter, and that it was therefore possible to deliver Quebec electricity to Prince Edward Island via New Brunswick. That proves that it is possible, in a deregulated system, to encourage provinces to improve inter-regional or interprovincial trade.

In the same spirit, having announced the deregulation or the easing of the regulation respecting the export of energy, yesterday or the day before, I forwarded to the Chairman of the National Energy Board major recommendations on interprovincial electricity trade. I asked the National Energy Board to hold public hearings on these matters, as I had asked the board, in September, 1986 to hold public hearings on the possibility of easing regulations in the area of exports.

I also contacted my colleagues from the provinces to inform them of such decision and asked them to express their viewpoint, if need be, to the National Energy Board over the next few months concerning the use of the

[*Text*]

sur cette question de l'utilisation des réseaux et de l'amélioration du commerce interprovincial ou interrégional.

Cela est en marche et se réalisera au cours des prochains mois. Je suis convaincu qu'après des réflexions, des audiences publiques et des recommandations de l'Office, nous serons en mesure, s'il y a lieu, d'améliorer nos politiques en ces matières.

Mr. Gustafson: First of all, I am very pleased that you are looking at the various options, and I want to assure you and Mr. Nystrom that there is a great deal of optimism, in Saskatchewan especially, with the upgrader at Lloydminster and the one that is currently being finished in Regina.

Mr. Minister, in response to the first question Mr. Gagnon asked, I was pleased to hear that you are looking at the small producer, particularly those under the $10 million bracket. If you want to go back on the program you announced some four years ago, which was very effective—I believe it was in Weyburn, Saskatchewan—this became so positive because many of the low-producing wells are pumped by these small companies and there is recovery of oil that is otherwise lost.

It seems to me we are looking at two things. We are looking here at security of market and security of supply. I want to assure you that there is a great deal of optimism. I live nine miles from the oilfield at Midale, Saskatchewan. That was the first field you visited, Mr. Minister, as a new minister, but I think one of the first discoveries in Saskatchewan away back in the 1950s.

• 1625

There is a great deal of optimism in three areas. First, we have secure markets, with the biggest market in the world right next to us, the United States. There is the optimism the free trade discussions bring, especially when the opposition becomes a little optimistic about the future, and there is the optimism we have in the energy field, because this is a long road and we have to plan for the future.

I think it is most important that you lay out options for Canada and for the future, and we do not just say we are in difficult times now and the prices are down. We all recognize that. We have been through the same thing in agriculture. Suddenly, what was a surplus becomes a shortage. I think history shows us is that there is about a 3% difference between a shortage and a surplus, and this is true in energy as well as food. I do want to commend you on that. I wondered if you had some comments specifically on secure markets.

[*Translation*]

networks and the improving of interprovincial and interregional trade.

The process is underway and will be completed over the next few months. I am convinced that after these exchanges of viewpoints, public hearings and recommendations to the Board, we will be able to improve our policies in that area, if necessary.

M. Gustafson: D'abord, je suis très heureux que vous examiniez les diverses possibilités, et je tiens à vous assurer, vous et M. Nystrom, que nous sommes assez optimistes, surtout en Saskatchewan, pour ce qui est de l'usine de valorisation à Lloydminster et celle que l'on est en train de terminer à Régina.

Monsieur le ministre, pour répondre à la première question de M. Gagnon, j'étais heureux de vous entendre dire que vous pensez aux petits producteurs, surtout à ceux qui sont dans la tranche de moins de 10 millions de dollars. Pour revenir au programme que vous avez annoncé il y a environ quatre ans, programme qui était très efficace—je crois que c'était à Weyburn, en Saskatchewan—ce programme s'est avéré tellement positif parce que bon nombre des puits à production peu élevée sont exploités par ces petites sociétés qui récupèrent ainsi du pétrole qui serait autrement perdu.

Il me semble que l'on veut assurer ici deux choses. On veut assurer la sécurité des marchés et la sécurité des approvisionnements. Je tiens à vous assurer qu'il y a pas mal d'optimisme. J'habite à neuf milles du champ de pétrole de Midale, en Saskatchewan. C'est le premier champ de pétrole que vous avez visité, monsieur le ministre, à titre de nouveau ministre, mais je pense qu'il s'agit également de l'un des premiers champs de pétrole qui ait été découvert en Saskatchewan dans les années 50.

Il y a pas mal d'optimisme dans le domaine. D'abord, nous devons assurer la sécurité des marchés, et le marché le plus important au monde se trouve tout près de nous, aux États-Unis. Les entretiens, en matière de libre-échange, apportent un certain optimisme, particulièrement lorsque l'opposition fait preuve d'un peu d'optimisme au sujet de l'avenir, et il y a de l'optimisme dans le domaine de l'énergie, parce que nous avons une longue route devant nous et que nous devons planifier pour l'avenir.

Il est à mon avis de toute première importance d'exposer les options pour le Canada et pour l'avenir et nous ne disons pas tout simplement que nous connaissons actuellement des moments difficiles et que les prix sont à la baisse. Nous reconnaissons tous cela. Nous avons connu la même chose dans le domaine de l'agriculture. On passe tout à coup des excédents à une pénurie. L'histoire montre qu'il y a une différence d'environ 3 p. 100 entre une pénurie et un excédent, et cela est tout aussi vrai dans le domaine de l'énergie que dans le domaine de l'alimentation. Je tiens à vous féliciter à ce sujet. Je me

[*Texte*]

Mr. Masse: First of all, I want to say that it is perfectly true that one of the first places I visited was Weyburn a couple of days after assuming responsibility for the department. I think we have been back there once or twice. We have opened a regional office for the CEDIP program, so your region is very close to my heart.

You are right to say that one of the problems we have is the security of markets and supply. To have security of supply, we have to secure markets. I do not have a magic answer to those things. If I had a magic answer, I would stop being the minister and become a consultant. I would make a fortune.

But we are in a world where we ask those questions, and we have to work together to find the answers. This energy option is one way to give a chance to Canadians who have some thoughts on this. The committee will have its own thoughts. I think it is a good opportunity to raise that issue and ask people who may have some thoughts to come to the committee and explain how it can be done, how it is done elsewhere and how it can be done here in Canada, and make recommendations to me.

I do not want to go too far in that direction today. Otherwise, why have committees if the minister has all kinds of answers for all those questions in his pocket? But it is a very good point. I have no problem with that, and I will await your comments on the matter. If you have a magic solution, I will be very pleased to implement it.

Mr. Gustafson: I think the comment I would have is that we must be optimistic, looking to all the opportunities that are ours. That is why I tend to differ with the comments made by Mr. Nystrom that the Lloydminster upgrader and that mega-project has a bright future, looking at all the opportunities there.

I can tell you again, having lived my lifetime in that oil field, that one of the greatest concerns is the security of market. The oil boys are happy when they have a market.

You hear a great deal of difference of expression travelling east and west, and that is always going to be the same. One is the concern of supply; the other is the concern of markets. But I think this report and your direction, Mr. Minister, bring a balance in looking at the options, and that is very, very important, in my mind.

Mr. Masse: You are right when you say that depending on where we are in Canada, we have a different view or a different interest in the word "energy". That is the reason

[*Traduction*]

demandais si vous aviez des commentaires sur la sécurité des marchés en particulier.

M. Masse: D'abord, j'aimerais dire qu'il est tout à fait juste que l'un des premiers endroits que j'ai visités quelques jours après avoir accepté la charge du ministère a été Weyburn. Nous y sommes retournés une ou deux fois, je crois. Nous avons ouvert un bureau régional dans le cadre du Programme canadien d'encouragement à l'exploration et à la mise en valeur, ce qui fait que votre région me tient fort à coeur.

Vous avez raison de dire que l'un des problèmes que nous avons est la sécurité des marchés et des approvisionnements. Pour avoir la sécurité des approvisionnements, nous devons assurer la sécurité des marchés. Je n'ai pas de réponse magique. Si j'en avais une, je cesserais d'être ministre et je deviendrais expert-conseil. Je ferais fortune.

Mais nous vivons dans un monde où nous posons ce genre de question, et nous devons travailler ensemble pour trouver des réponses. Cette confluence énergétique est une façon de donner l'occasion aux Canadiens de faire connaître leurs points de vue à ce sujet. Le Comité a son propre point de vue. Je pense qu'il s'agit d'une bonne occasion de soulever la question et de demander aux gens qui ont peut-être une opinion, de venir l'expliquer au Comité, d'expliquer de quelle façon on le fait ailleurs et comment on peut le faire ici au Canada, et de me faire des recommandations.

Je ne veux pas trop m'engager dans cette direction aujourd'hui. Autrement, pourquoi aurait-on des comités si le ministre connaît toutes les réponses? Mais le point que vous soulevez est excellent. Cela ne pose aucun problème, et j'attendrai vos commentaires à ce sujet. Si vous avez une solution magique, je serai très heureux de la mettre en oeuvre.

M. Gustafson: À titre de commentaire, je dirais que nous devons être optimistes, étant donné toutes les possibilités qui s'offrent à nous. C'est pourquoi je serais plutôt enclin à ne pas être d'accord avec les observations de M. Nystrom lorsqu'il dit que l'usine de valorisation de Lloydminster, ce mégaprojet, a un avenir brillant, étant donné toutes les possibilités là-bas.

Je peux vous dire encore une fois, ayant vécu toute ma vie dans ce champ de pétrole, que l'une des plus grandes préoccupations est la sécurité des marchés. Les sociétés pétrolières sont heureuses lorsqu'elles ont un marché.

Les points de vue sont très différents selon qu'ils proviennent de l'Est ou de l'Ouest, et cela sera toujours le cas. D'un côté, on est préoccupé par les approvisionnements, de l'autre, par les marchés. Mais je pense que le présent rapport ainsi que votre directive, monsieur le ministre, apportent un certain équilibre dans la façon d'envisager la confluence énergétique, ce qui est très important pour moi.

M. Masse: Vous avez raison lorsque vous dites que selon l'endroit où l'on se trouve au Canada, on a un point de vue différent ou un intérêt différent au sujet du mot

[*Text*]

why it is so important, as Canadians, to know more about energy. Many Canadians have a very regional approach to energy, a very regional knowledge about energy. From Calgary to Montreal, from Toronto to Lloydminster, we have to have a better knowledge of energy.

It is in that sense that I have asked my communications branch to be more active in schools and universities. We will have a great opportunity. Next year, the World Conference on Energy will be in Montreal. I think 4,000 or 5,000 official delegates from all over the world will be there. We should use that opportunity not only to explain how important Canada is in terms of energy—we are blessed, by God, in every sector—but also to explain to all Canadians what is behind energy.

• 1630

When Champlain landed in Nova Scotia, at Port Royal, in 1603, he was with Marc Lescarbot, who wrote pieces for the theatre and things like that. But Lescarbot also wrote about energy, and he explained to the people in Europe that one of the reasons why Canada would have a great future is because it is backed by energy. So if it was true for Marc Lescarbot in 1603, it is still true for us in 1988. Canadians should know that one of the reasons for the success of their country is energy.

I hope we will have another opportunity together, but it is now 4.30 p.m.

The Chairman: Just one quick question from Mr. MacLellan.

Mr. MacLellan: I just wanted to mention the minister's text, where he refers to mega-projects: "As well, by enhancing Canada's domestic energy supplies, they contribute to Canada's energy security". That is not necessarily the case with the free trade agreement, because there is no insurance that any of this energy that is produced by the mega-projects will remain in Canada. In fact, the $3 billion plus that we could put into Hibernia, all of the oil developed could go to the United States market.

With regard to *Energy Options*, when they refer to reserves for Canadians, they do not talk about reserves, they talk about hoarding Canadian energy. So the government and *Energy Options* are agreed on one thing: that Canadians do not have to worry about security of supply. Yet you are saying that this is what is going to happen. It seems, Mr. Minister, that there is not an energy policy.

The Chairman: It is a long question.

[*Translation*]

énergie. C'est pourquoi il est tellement important, en tant que Canadiens, d'en connaître davantage en matière d'énergie. Bon nombre de Canadiens ont une optique très régionale de l'énergie, des connaissances très régionales de la question. De Calgary à Montréal, de Toronto à Lloydminster, nous devons avoir une meilleure connaissance de l'énergie.

C'est dans cet esprit que j'ai demandé à la Direction des communications de mon ministère d'être davantage active dans les écoles et les universités. Nous aurons une excellente occasion de le faire. L'an prochain, la conférence mondiale sur l'énergie se tiendra à Montréal. Je pense que 4,000 à 5,000 délégués du monde entier seront là. Nous devrions profiter de l'occasion, non seulement pour expliquer combien le Canada est important sur le plan des ressources énergétiques, dont la nature nous a généreusement pourvus, mais également pour faire comprendre à tous les Canadiens tout ce que l'énergie représente.

Lorsque Champlain a débarqué en Nouvelle-Écosse, à Port Royal, en 1603, il était accompagné de Marc Lescarbot, qui a écrit des pièces de théâtre et autres oeuvres. Néanmoins, Lescarbot a également écrit sur l'énergie et il a expliqué aux Européens que l'une des raisons pour lesquelles le Canada était promis à un grand avenir est qu'il possédait de vastes ressources énergétiques. Si c'était vrai aux yeux de Marc Lescarbot en 1603, ce l'est toujours pour nous en 1988. Les Canadiens devraient savoir que l'énergie est l'une des raisons de la prospérité de leur pays.

J'espère que nous aurons une nouvelle occasion de nous réunir, mais il est maintenant 16h30.

La présidente: Pouvez-vous seulement répondre à une brève question de M. MacLellan?

M. MacLellan: Je voudrais seulement mentionner les propos que le ministre tient dans son discours, au sujet des mégaprojets: «ainsi, en accroissant les approvisionnements énergétiques du Canada, ils contribuent à assurer notre sécurité énergétique». Ce n'est pas nécessairement vrai avec l'Accord de libre-échange étant donné que rien ne garantit que l'énergie produite par les mégaprojets restera au Canada. En fait, les 3 milliards et plus que nous pourrions investir dans Hibernia, la totalité du pétrole produit là-bas, pourraient aller vers le marché des États-Unis.

Quant aux auteurs du rapport, lorsqu'ils parlent de constituer des réserves pour les Canadiens, en réalité, ils parlent de thésauriser l'énergie canadienne. Par conséquent, le gouvernement et les auteurs de *Confluences énergétiques* sont d'accord sur un point, à savoir que les Canadiens n'ont pas à s'inquiéter de la sécurité des approvisionnements. Pourtant, vous dites que c'est ce qui va se passer. Apparemment, monsieur le ministre, il n'existe aucune politique énergétique.

La présidente: C'est une longue question.

[*Texte*]

Mr. MacLellan: Yes. With regard to your new electricity policy, the *Energy Options* report is concerned about environmental risks, whether they are going to be considered.

M. Masse: Tout d'abord, l'Accord de libre-échange, dans notre esprit, favorisera la sécurité des approvisionnements. Pourquoi? Parce que si le pétrole qui est dans le sol n'est pas extrait, il ne contribue en rien à la sécurité des approvisionnements. À l'avenir, les investissements seront de plus en plus importants. L'investissement est important, et l'assurance de marchés est fondamentale pour attirer les investissements. C'est un peu une réponse à la question de notre collègue sur la sécurité des marchés par rapport à la sécurité des approvisionnements. L'un porte l'autre jusqu'à un certain point. L'Accord de libre-échange, en assurant un marché plus vaste, permettra de développer des ressources qui, autrement, ne seraient peut-être pas développées. Dans cet esprit-là, le libre-échange contribue à la sécurité des approvisionnements.

Deuxièmement, il y a la question de l'électricité et de l'environnement. Je suis très sensible, comme vous le savez, à l'aspect environnemental en matière énergétique. C'est dans cet esprit-là que, lors des discussions avec les provinces sur l'assouplissement de la réglementation, le gouvernement canadien a fait de l'environnement l'un des points importants de la politique de déréglementation de l'électricité. Pour la première fois, sous le leadership du gouvernement canadien, le fédéral, les provinces et les sociétés publiques qui ont des intérêts dans le domaine de l'électricité définiront ensemble des normes en matière de lignes de transport et en matière de développement des ressources hydrauliques ou autres. Ces normes étant définies, il appartiendra d'abord aux provinces d'en assurer le respect. Mais s'il advient que le gouvernement canadien, ou l'Office national de l'Énergie, a des doutes quant à l'application de ces normes dans un projet spécifique, on pourra recommander au gouverneur en conseil de tenir des audiences publiques sur ce sujet particulier, ce qui est nouveau et qui n'était pas dans la politique précédente.

• 1635

En termes d'environnement, donc, il y a plus dans la politique actuelle qu'on ne retrouvait pas dans la politique passée. Et dans ce sens-là, je suis convaincu que le secteur environnement est mieux protégé maintenant qu'il l'était avec l'ancienne politique.

The Chairman: Thank you very much, Mr. Minister. I am quite sure that once the committee... We will be meeting in camera in a few minutes to discuss how we are going to pursue the *Energy Options* report. We certainly will have many more questions, and we would very much like to see you back at a later date, perhaps. But we want to thank you for taking time out today to visit with us, and we look forward to seeing you again soon.

[*Traduction*]

M. MacLellan: En effet. En ce qui concerne votre nouvelle politique à l'égard de l'électricité, *Confluences énergétiques* émet des inquiétudes au sujet des risques écologiques et dit qu'il faudrait en tenir compte.

Mr. Masse: First, in our mind, the Free Trade Agreement will increase security of supply. Why? Because if we do not extract our oil it will not contribute to security of supply. Investments will be bigger and bigger in the future. Investment is important and a guaranteed market is essential to attract investors. This is to answer our colleague's question about market security as opposed to security of supply. Both are interrelated to a certain extent. By extending the market, the Free Trade Agreement will allow us to develop resources which otherwise might stay in the ground. In that spirit, free trade will contribute to security of supply.

Second, there is the issue of electricity and environment. As you know, I am very sensitive to the environmental aspect of energy. It is in that spirit that the Canadian government made environment one of the main issues in its discussions with the provinces on electricity deregulation. For the first time, under the leadership of the Canadian government, the federal, provinces and Crown corporations that have a vested interest in electricity will define together the standards for a transmission line and the development of hydraulic and other resources. Once those standards will be defined, it will be the responsibility of the provinces to ensure their implementation. But if the Canadian government, or the National Energy Board, has any doubt concerning the implementation of those standards within a specific project, it will be able to ask to the Governor in Council to hold public meetings on that subject, which was not provided for in the previous policy.

Then, there is more concerning environment in the new policy than there was in the previous one. So, I am convinced that our environment is better protected now than it was before.

La présidente: Merci beaucoup, monsieur le ministre. Je suis sûre qu'une fois que le Comité... Nous allons nous réunir à huis clos dans quelques minutes pour voir comment nous allons poursuivre l'étude du rapport *Confluences énergétiques*. Nous aurons sans doute beaucoup d'autres questions à poser et nous aimerions beaucoup vous voir revenir à une date ultérieure. Néanmoins, nous tenons à vous remercier d'avoir pris le temps de venir nous voir aujourd'hui et nous espérons vous revoir bientôt.

[*Text*]

Mr. Masse: Thank you. I have been very pleased to be with you, and I hope I will have another opportunity to discuss energy matters with you whenever you please.

The Chairman: The committee will now go in camera to discuss the methodology for reviewing the *Energy Options* report.

[*Translation*]

M. Masse: Merci. Tout le plaisir était pour moi et j'espère avoir de nouveau l'occasion de discuter avec vous des questions énergétiques lorsque vous le désirerez.

La présidente: Le Comité va maintenant se réunir à huis clos pour discuter de la méthodologie à adopter pour examiner le rapport *Confluences énergétiques*.

Canada Post Postage paid
Postes Canada Port payé

Book rate Tarif des livres

K1A 0S9
OTTAWA

If undelivered, return COVER ONLY to
Canadian Government Publishing Centre,
Supply and Services Canada,
Ottawa, Canada, K1A 0S9

En cas de non-livraison,
retourner cette COUVERTURE SEULEMENT à
Centre d'édition du gouvernement du Canada,
Approvisionnements et Services Canada,
Ottawa, Canada, K1A 0S9

WITNESS

From the Department of Energy, Mines and Resources:

George Anderson, Assistant Deputy Minister, Energy Policy Sector.

TÉMOIN

Du ministère de l'Énergie, des Mines et des Ressources:

George Anderson, sous-ministre adjoint, Secteur de la politique énergétique.

Available from the Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Canada K1A 0S9

En vente: Centre d'édition du gouvernement du Canada, Approvisionnements et Services Canada, Ottawa, Canada K1A 0S9

CANADA

INDEX

STANDING COMMITTEE ON

Energy, Mines and Resources

HOUSE OF COMMONS

Issues 1-49 • 1986-1988 • 2nd Session • 33rd Parliament

Chairperson: Barbara Sparrow

Published under authority of the Speaker of the House of Commons by the Queen's Printer for Canada.

Available from the Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Canada K1A 0S9

Publié en conformité de l'autorité du Président de la Chambre des communes par l'Imprimeur de la Reine pour le Canada.

En vente: Centre d'édition du gouvernement du Canada, Approvisionnements et Services Canada, Ottawa, Canada K1A 0S9

GUIDE TO THE USERS

This Index is a subject-based and cross-referenced index which provides subject analysis as well as corresponding entries under the names of individual Members of Parliament.

Each participating Member and witness has a global entry, based on the order of reference that covers all pages where he/she spoke.

Knowles, Hon. Stanley (NDP—Winnipeg North Centre)
Regional Economic Expansion Department estimates,
1984-1985, main, **15**:9, 11-2, 19

Issue page

Testimony and debate are analysed for subject content and the entries are arranged alphabetically.

Member subject entry — **Knowles**
Steel industry, **15**:9

Main subject sub-heading — **Steel industry**
Exports, **15**:9

Included in the index are several headings that may be particularly useful; a list under Witnesses shows all appearances by organizations before the Committee; the heading Orders of Reference lists all matters studied by the committee; the section Procedure and Committee business records all items of a procedural nature including those listed in the Minutes.

The index is extensively cross-referenced to account for organization of subject detail and varying terminology. Cross-references to a first sub-heading are denoted by a long dash "—".

Women *see* Canadian Forces—Training

A list of dates of meetings of the committee with the corresponding issue numbers may be found under the heading "Dates and Issues" on the following page.

The most common abbreviations found in the Index are as follows:

A = Appendices Amdt. = Amendment M. = Motion S.O. = Standing Order

Political affiliations: L = Liberal PC = Progressive Conservative NDP = New Democratic Party Ind = Independent Ind-L = Independent Liberal

For further information contact the
Index and Reference Branch—992-8976

INDEX

HOUSE OF COMMONS STANDING COMMITTEE

OFFICIAL REPORT

SECOND SESSION—THIRTY-THIRD PARLIAMENT

DATES AND ISSUES

—1986—

October:	21st, 1.
November:	4th, 1; 17th, 18th, 2; 24th, 3; 27th, 4.
December:	1st, 4; 2nd, 5; 4th, 11th, 6.

—1987—

January:	21st, 22nd, 6; 26th, 7.
February:	5th, 7; 10th, 8; 19th, 9.
March:	3rd, 10; 5th, 11; 10th, 12; 17th, 24th, 13; 31st, 14.
April:	7th, 9th, 14; 14th, 15; 15th, 16; 28th, 29th, 17; 30th, 18.
May:	5th, 19; 12th, 20; 13th, 21; 19th, 22; 21st, 23, 24; 26th, 28th, 25.
June:	2nd, 9th, 11th, 18th, 25th, 25; 30th, 26.
August:	20th, 26.
September:	16th, 26; 17th, 27; 29th, 28.
October:	6th, 15th, 29.
November:	3rd, 29; 4th, 30; 18th, 31, 32; 19th, 33.
December:	1st, 34, 35; 2nd, 36; 15th, 37; 16th, 38.

—1988—

January:	21st, 39.
February:	10th, 39.
March:	2nd, 39; 4th, 40; 10th, 41; 16th, 29th, 42.
May:	10th, 42; 11th, 43; 16th, 44; 19th, 45; 25th, 46.
June:	1st, 2nd, 8th, 13th, 16th, 47; 21st, 48.
September:	20th, 49.

INDEX

COMITÉ PERMANENT DE LA CHAMBRE DES COMMUNES
COMPTE RENDU OFFICIEL

DEUXIÈME SESSION, TRENTE-TROISIÈME LÉGISLATURE

DATES ET FASCICULES

—1986—

Octobre:	le 21, f.1.
Novembre:	le 4, f.1; les 17 et 18, f.2; le 24, f.3; le 27, f.4.
Décembre:	le 1er, f.4; le 2, f.5; les 4 et 11, f.6.

—1987—

Janvier:	les 21 et 22, f.6; le 26, f.7.
Février:	le 5, f.7; le 10, f.8; le 19, f.9.
Mars:	le 3, f.10; le 5, f.11; le 10, f.12; les 17 et 24, f.13; le 31, f.14.
Avril:	les 7 et 9, f.14; le 14, f.15; le 15, f.16; les 28 et 29, f.17; le 30, f.18.
Mai:	le 5, f.19; le 12, f.20; le 13, f.21; le 19, f.22; le 21, f.23 et f.24; les 26 et 28, f.25.
Juin:	les 2, 9, 11, 18 et 25, f.25; le 30, f.26.
Août:	le 20, f.26.
Septembre:	le 16, f.26; le 17, f.27; le 29, f.28
Octobre:	les 6 et 15, f.29.
Novembre:	le 3, f.29; le 4, f.30; le 18, f.31; le 18, f.32; le 19, f.33.
Décembre:	le 1er, f.34 et f.35; le 2, f.36; le 15, f.37; le 16, f.38.

—1988—

Janvier:	le 21, f.39.
Février:	le 10, f.39.
Mars:	le 2, f.39; le 4, f.40; le 10, f.41; les 16 et 29, f.42.
Mai:	le 10, f.42; le 11, f.43; le 16, f.44; le 19, f.45; le 25, f.46.
Juin:	les 1er, 2, 8, 13 et 16, f.47; le 21, f.48.
Septembre:	le 20, f.49.

GUIDE DE L'USAGER

Cet index couvre les sujets ayant fait l'objet de discussions lors des séances de ce comité. Les dates et les numéros des fascicules contenant les procès-verbaux et témoignages des séances du comité sont répertoriés dans les pages préliminaires sous le titre «DATES ET FASCICULES».

Les sujets, ainsi que les noms des intervenants, sont inscrits par ordre alphabétique et en caractères gras de même que les numéros des fascicules. Chaque référence peut apparaître sous les deux rubriques afin de faciliter l'accès à l'information.

Pêches
Pacifique, **11**:31

Oberle, M. F. (PC—Prince George—Peace river)
Pêches, **11**:31

L'exemple suivant illustre la méthode d'indexation employée.

sujet général————**Office canadien du poisson salé**
sujet particulier————Activités, **19**:17; **27**:4-9

numéros de fascicules — numéros de pages

Certains sujets d'importance commandent des descripteurs spéciaux tels que: Appendices; Ordre de renvoi; Procédure et Règlement; Témoins; Votes en Comité, etc.

L'index est dit croisé parce qu'il comporte des renvois. Les renvois à un sous-titre sont indiqués par un long trait.

Nigeria. *Voir* Poisson—Exportations

sujet abordé————**Géothermie**
sous cette autre rubrique — Allusions, **1**:34; **11**:4-18
Voir aussi Chauffage collectif, système

titre-sujet préféré à un autre — **Énergie atomique.** *Voir plutôt* Énergie nucléaire

Les abréviations et symboles employés sont les suivants:

A=appendice. Am.=amendement. Art.=article. M.=motion.

Affiliations politiques: L — Libéral; PC — Progressiste conservateur; NPD — Nouveau parti démocratique; Ind. — indépendant; L Ind. — Libéral indépendant.

S'adresser à la division de l'Index et références pour toute demande de renseignements additionnels—992-7645

Publié en conformité de l'autorité du Président de la Chambre des communes par l'Imprimeur de la Reine pour le Canada.

En vente: Centre d'édition du gouvernement du Canada, Approvisionnements et Services Canada, Ottawa, Canada K1A 0S9

Published under authority of the Speaker of the House of Commons by the Queen's Printer for Canada.

Available from the Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Canada K1A 0S9

CANADA

INDEX

DU

COMITÉ PERMANENT DE

L'Énergie, des mines et des ressources

CHAMBRE DES COMMUNES

Fascicules n^{os} 1-49 • 1986-1988 • 2^{e} Session • 33^{e} Législature

Présidente: Barbara Sparrow